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A LITERATURE REVIEW OF BRAND PERSONALITY ATTRIBUTES ON CUSTOMER BUYING DECISION IN THE 21ST CENTURY MARKET

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Abstract

In the 21st century market, the idea of brand personality is been significant in branding and brand management literature. This study aims to provide a review of literature on brand personality and customer buying decisions. The paper is a critical evaluation of current literature, examining the development of brand personality and its relationship with consumer buying behaviour. In doing so, the paper reviewed and conceptualized some works that are connected to the current research theme through scientific databases such as Emerald Insight, Scopus, EBSCO, Web of Science, Google Scholar, among others. The study employed content analysis of literature as the main research method with focus on brand personality dimensions of sincerity, excitement, competence sophistication, and ruggedness, which are essential dimensions of brand personality. The major finding is that brand personality dimensions are significant drivers of consumer buying decisions and post purchase behaviour. However, the nature of the relationship is dependent on individual, product, and market factors, which are varied. This review expands the foundations for the development of the brand personality and its dimensions. Furthermore, the paper observes the application of the brand personality concept to consumer behaviour. Ultimately, the paper contributes to the branding literature by providing a critical evaluation of a major branding concept and by providing insights into its role in the modern brand theory.

Keywords: *Brand Personality, Brand Attributes, Consumer Buying Decision, Sincerity, Excitement, Competence, Sophistication, Ruggedness*

1 INTRODUCTION

A brand's personality is simply the human traits that are associated with the brand. Brand personality helps to create a relationship between the customer and the brand. This is because there are people who like to associate themselves with a certain brand because of its personality (Jibril, Kwarteng, Chovancova, & Vykydalova, 2019). For example, an individual may want to be associated with a brand that is perceived to be strong. Men like being associated with masculine products and women with feminine products. Larson (2002) explains that the brand personality is when what comes to mind about a brand's name, see, smell, taste, or touch. In his view, "it's that first involuntary thought that comes to their mind" (Larson, 2002). Larson (2002) also noted that marketers must learn and clearly understand the consumer's feelings, habits, motivation, insecurities, prejudices, and desires.

Jibril, Chovancova, Hoang, and Hung (2019) explain that brand personality has been a popular subject in marketing and advertising because choosing the right personality characteristics for a brand plays an important role in representing the unique personalities of consumers and the brands they use. The notion of a brand personality is often linked to the level of customer satisfaction. Intuitively, a strong and positive brand personality leads to favourable attitudes of consumers toward brands (Maehle et al., 2011). Research has shown that customers are more involved in the products that they perceive to satisfy their needs (Guha et al., 2018), and these kinds of perceptions originate from the characteristics and features of the brand, which make

up the personality of the brand. Consumers view brands not only through rational judgment of functional features and benefits but also through the presence of symbolic meanings that lend additional value to brands. Findings by Bempong (2017) indicated increasing concerns about understanding and measuring these symbolic meanings to emphasize the uniqueness of their brands and to differentiate them from other competitors.

The notions that brands have a personality and that the relationship between consumers and brand personality is very significant for success are regarded as the most important concepts in the fields of marketing and advertising (Freling & Forbes, 2005). According to Freling and Forbes (2005), advertising practitioners stress brand personality in developing advertising strategies and try to prove that particular brand personalities yield positive consequences.

Owing to the varied knowledge in the literature on brand personality and its constructs, this paper seeks to conduct a review of literature on brand personality dimensions from both positive and negative views. The paper examines the multidimensionality of the brand personality construct (i.e., why consumers infuse human personality into brands) and the effect of brand personality attributes on the customer's buying decision. This paper would be a wake-up call for scholars and brand practitioners on the need to reconsider brand personality in the consumer market since competition continues to heighten in the retail market across the globe, particularly in this 21st century market.

2 LITERATURE REVIEW

This section makes a review of literature on brand personality and its attributes.

2.1 Brand personality

Brand personality may be described as a collection of meanings describing the "inner" features of a brand. These meanings are based on the behaviour of consumers with personified brands (Davies et al., 2018). Measures of brand personality are frequently used to operationalize intangible brand connections, and the method has proven beneficial to both academics and practitioners in understanding the implications of such associations with a brand (Japutra & Molinillo, 2019). The personality of the brand is defined as the human properties of a brand that make it unique in comparison to other brands (Bairrada et al., 2019). According to Kumar (2018), brand personality is a combination of characteristics that apply and are significant both to brands. Based on the brand identity prism developed by Kapferer (Ianenko et al., 2020), a brand's identity when communicating with consumers consists of six aspects: physique, personality, culture, relationship, reflection, and self-image; in which personality refers to characteristics associated with the brand. Aaker earlier explained that a brand's personality traits can be compared to the "Big Five" human personality traits (Lara-Rodríguez et al., 2019). These five traits are: "Sincerity, Excitement, Competence, Sophistication, and Ruggedness". Through these qualities, a brand's personality may be measured to gather information on how the public understands and how management wants it to be viewed. Brand personality affects interactions between consumers and brands (Radler, 2018). In the market, consumers are connected to several brands each day. Therefore, brands are a key part of consumer decision-making, buying intention, and strong engagement with a brand (Radler, 2018).

2.2 Sincerity

Sincerity is connected to the characteristics of being down to earth, familiar, little, honest, sincere, true, healthy, original, joyful and pleasant (Wisetsri, 2018). Since they follow and convey ethical practices, dedication, or care for the consumer, sincere brands are often seen as this (Gumparthi & Patra, 2020). In order to prevent uncertainties, build excellent connections

with the customer, and to assist employees and the social and natural environment, sincere brands frequently use clear consumer policies. Sincere brands rarely engage in scandal or controversy (Wisetsri, 2018). Instead, they see and operate as part of a wider set of communal societies. As a result of any or all of these activities, customers (or society as a whole) consider them to be honest (Gumparthi & Patra, 2020).

2.3 Excitement

Excitement is associated with the characteristics of audacious, moving, thrilling, cool, youthful, inventive, original, up-to-date, independent and modern (Wisetsri, 2018). Thus, they typically utilize bright logos, non-ordinary typefaces, that are shown in unexpected and interesting locations and settings. This personality is often visible in sports tournaments and major music events. The team of managers works hard to encourage and stimulate the consumer, as businesses that "think outside the box" (Gómez-Suárez et al., 2017).

2.4 Competence

Competence pertains to reliability, strength, security, intellect, engineering, business, success, leadership, and trust (Xue et al., 2020). Competent brands are mostly viewed as dependable, accountable, clever and efficient. These impressions frequently rely on the performance of a product or service and how the company acts in society and the market (Portal et al., 2018). Therefore, branding is commonly displayed with visible lettering and colours that convey trust (like blue and white). Furthermore, their ambassadors tend to be knowledgeable of the product or be perceived as trustworthy. According to Portal et al. (2018), other common practices include a tendency to highlight the quality of suppliers and efficient production practices.

2.5 Sophistication

Sophistication implores the high quality, glamorous, good-looking, delightful, feminine and smooth features of sophistication (Banahene, 2017). Those brands have a high-class, romantic, charming, pompous, and glamorous perception by customers. It is therefore no surprise to think that sophisticated brands are often found across luxury sectors and among top-priced brands in other industries (for their product categories) (Kim & Phua, 2020). Sophisticated branding applications may range from fashion, accessories (watches and clothing) to vehicles, medical equipment, food, and restaurants throughout a wide range of sectors. It is also popular in women's brands or branches (Portal et al., 2018). Brands frequently use delicate and thin typefaces, simple designs, light colours, and are linked with appealing and upmarket surroundings to communicate elegance. They are also frequently shown in affluent settings.

2.6 Ruggedness

This dimension comprises trademarks associated with the outdoors, toughness, masculinity, and westernism, for example. Ruggedness includes characteristics such as being outdoorsy, manly, western, rugged, and tough (Keni & Esmeralda, 2021). As a result, rugged brands tend to be more male-oriented. The overarching goal is to communicate the impression that the product is resistant, durable, and designed for individuals who are bold, willing to take chances, fearless, and do not want to live an average life (Changchenkit, 2018). Out of the five dimensions, "Ruggedness" is termed as the weakest. This is a potential reason for the emergence of ruggedness as one of the dimensions of brand personality which otherwise should not be there at all (Keni & Esmeralda, 2021).

2.7 Customer Purchasing Behaviour

The process of purchasing an item or service is referred to as consumer purchasing behaviour (Katrodia et al., 2018). A consumer does not generally make a purchase without thoroughly considering his or her needs. Consumer behaviour may be defined as a method through which customers utilize a step-by-step procedure to acquire and use the goods and services they desire (Katrodia et al., 2018). The choice to buy is always made by the customer, who must meet their needs and desires with the items and services they wish to obtain. Consumer behaviour refers to the many aspects of the decision-making process that lead customers to purchase and consume a product (Princes, 2019). All of these factors have a significant influence on the items that consumers buy. Some customers buy items on a regular basis because they are pleased with their performance. It is difficult to identify how customers purchase since the decision-making process occurs in the brains of the consumers and it is difficult to adequately observe how decisions may be made. The decision-making process occurs here because the consumer purchasing model may explain or reveal how various internal and external factors influence purchase decisions (Pal & Shukla, 2020). The consumer purchasing decision process is divided into five stages: problem detection, information search, alternative evaluation, purchase choice, and post-purchase behaviour. It demonstrates how a buyer begins to consider a product before purchasing it. During the product decision-making process, the buyer can employ all five stages. The buyer may also be able to bypass one or more phases; it all relies on the consumer's perspective (Kotler & Armstrong, 2017).

2.8 Consumer Buying Decision

According to Stankevich (2017), the consumer decision-making process is a step-by-step procedure that customers employ while purchasing goods or services. The steps that buyers go through before and after completing a purchase are considered in consumer buying behaviour. According to Qazzafi (2019), decision making, and psychological activity are involved while assessing, purchasing, consuming, or ordering products and services. The consumer buying decision process is the decision-making process that begins with the consumer purchasing products or services in the market in exchange for money before, during, and after the purchase of goods or services (Kotler & Armstrong, 2017). It helps the seller or marketer sell their goods or services in the market. If a marketer is effective in understanding customer behaviour as it relates to the consumer purchasing decision process for products or services, the marketer may be successful in selling its goods or services.

3 METHODOLOGY

The overall objective of this study is to examine brand personality literature and consumer buying decisions and behaviour. This study is based solely on qualitative research. In particular, the authors of the paper used content analysis to achieve the main objective of the research. The research is completely theoretical, and no primary was used in this study. The collection of data was done using secondary data such as books, websites, blogs, published papers, and research journal articles. The data collected was analysed using content analysis. While the content analysis was considered a simplified methodology for this study, it is a very good starting point to identify an existing and relevant issue with broader coverage (Neuendorf & Kumar, 2015). In this respect, articles were gathered from open databases like SCOPUS, EBSCO, Thomson Reuter, WoS, and Google Scholar using a keyword search of the main themes: Brand Personality Dimensions and Consumer Buying Behaviour. The researchers also use thematic analysis to deepen their comprehension. This approach offers the writers the right benefit in the interaction of the current study, given the interaction of the relationships and patterns across different articles.

4 DISCUSSION OF PREVIOUS FINDINGS

A brand's personality must be accessible and recognizable to target consumers for it to appeal to them and ultimately influence their purchase decisions. Many studies have identified the relationship between brand personality dimensions and consumer buying decisions. Bouhlel et al. (2011) observed that brand personality dimensions of competence and sincerity influence brand loyalty, trust, and commitment. In effect, this affects customer loyalty and attachment as well as a commitment to the sincere and competent brand. Yeoh et al. (2014) also found that sincerity, excitement, and competence of a brand significantly affect brand loyalty. A study by Cuevas (2016) on exploring brand personality within the blogosphere found that consumers identify a brand as sincere when their expectations for positive experiences are met. In another finding, consumer brand choice was positively influenced by a brand that provides consumers with personal selling and guarantees such as positive service experiences and promotional incentives, both contribute to the perceived sincerity of a brand (Maehle et al., 2011).

Sincerity is also established through passion and personalization, traits which are often presented by human brands such as bestselling authors and fashion bloggers (McQuarrie et al., 2013). N'Goala and Morrongiello (2014) also report that brand sincerity is a potent factor in determining consumer engagement as trustworthiness drives consumers to willingly communicate their own opinions through comments or evaluations online. Sung and Kim (2010) found a link between brand personality traits, including sincerity and excitement in particular, and brand trust. Findings from their study parallel those from studies in marketing and the other disciplines of management and psychology where positive traits like sincere concern for others and agreeableness have been linked to trustworthiness perceptions while both favourable traits of excitement and sincerity are positively related to trust. However, prior work on trust by Sung and Kim (2010) suggests that sincerity is superior to excitement in trust development, and a stronger relationship is expected to be found for the trait of sincerity.

Walsh et al. (2015) also report that emotions such as excitement play a critical role in consumer experience, influencing perceptions, consumer engagement, and ultimately a brand choice. Sincerity (along with competence) also has been found to have the largest influence on brand attitudes and commitment (Eisend & Stokburger-Sauer, 2013). Brand sincerity also facilitates brand relationships and influences brand trust (Eisend & Stokburger-Sauer, 2013; Sung & Kim, 2010).

Sincerity and excitement traits are also often inversely correlated and regularly yield different responses from consumers (Lovett et al., 2014). A study by Malär et al. (2012) on emotional brand attachment and brand personality found that companies are searching for ways to create increasingly, strong emotional brand connections with consumers. This is motivated by the finding that such connections lead to higher levels of consumer loyalty, which increases company financial performance (Park & John, 2010). In the case of brand personality and the technology industry, Aberathna and Ubeyachandra (2017) reported a weak positive impact of brand excitement on emotional brand attachment in laptop industry in Sri Lanka. Silva and Fernando (2015) reported a positive relationship between brand sophistication and consumers' brand loyalty on mobile telecommunication services in Sri Lanka. However, de la Paz Toldos-Romero and Orozco-Gómez (2015) did not find a relationship between brand sophistication and purchase intention.

Dewi et al. (2015) also found a positive but insignificant relationship between brand sophistication and brand trust. Furthermore, Al Mashady et al. (2019) observed that there is a significant influence relationship between brand sophistication and a firm's supply chain process. However, Cuevas (2016) found no relationship between ruggedness and customer loyalty in a case study of Samsung mobile phone users.

From the findings of the various studies presented above. The various brand personality dimensions have been found to have varying effects on consumers. The authors of the paper therefore conceptualize and propose a framework (model) for a future empirical inquiry (see Figure 1).

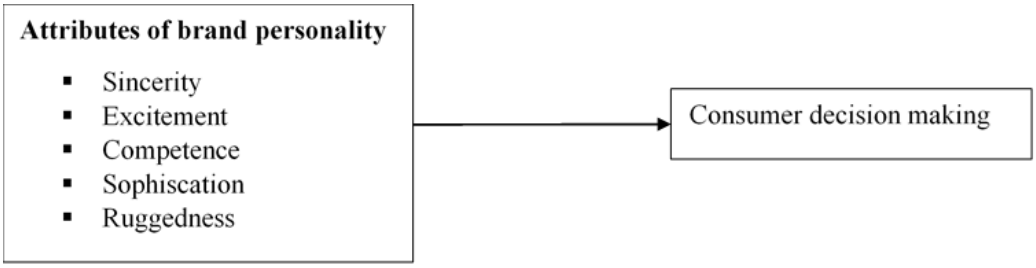

Fig. 1 – A link between brand personality attributes and consumer decision making. Source: own research

The model is developed based on the ascertainment of knowledge from literature review that consumers are frequently driven to purchase items and brands in order to meet their personal aspirations. Brands, in particular, are crucial for customers who want to identify with their brand personality. Well-known brands with appealing personalities, such as sophisticated and thrilling, provide customers the chance to appropriate the brand's personality and integrate it with their self-image.

This research used a review of literature to establish conclusions and findings. Future research should consider using an empirical survey to validate the findings. This study sought to establish brand personality influence on consumer buying decision. However, brand personality impact on consumer purchasing decision can be influenced by the type of product. Thus, the type of product can be employed as a moderating variable in future studies.

5 STUDY IMPLICATION

The objective of this research was to literature and further conceptualize and develop a framework of the five brand personality dimensions: Sincerity, Excitement, Competence, Sophistication, and Ruggedness; and its impact on customer decision-making. This research holds both theoretical and practical implications.

Theoretically, the brand personality framework developed in this research will suggest the nature of the asymmetric relationship between brand personality and customer decision-making. Although this study enlightens the literature on brand management, it is not without its limitations. The review offers a better understanding of consumers' perceptions and attitudes toward brands and brand personality. The reviewed literature showed that attaching personalities to brands can make them more desirable to the consumer. The study will contribute to the literature by its attempt to classify brand personality dimensions by their effect on consumer buying decisions. The existing literature, however, has hardly explored the links between the various brand personality dimensions and consumer buying decisions.

The review also has consequences for practitioners, not just in the measurement of brand personality, but also in brand marketing. If humans instinctively evaluate a brand for its sincerity, competence, and status on grounds of basic human needs, as the authors of the paper propose in theory, then marketers must guarantee that they offer signals for their marketplace to position their brands on a single dimension. Again, managerially, this is important, because firms and agencies can use this knowledge to control the personality of their brand, to make consumers perceive the desired brand personality. Failure to do so will undoubtedly result in

potential consumers and workers using every information they can to assess the brand on every level.

6 CONCLUSION AND FUTURE RESEARCH DIRECTION

This research aims to examine the relationships between brand personality and consumer buying decisions. In doing so, the paper conducts a review of the literature with a focus on the conceptualization, development of the conceptual model of dimensions/attributes of brand personality. Noticeably, the study found some brand personality dimensions can influence consumer related variables but in the context depending on the product or service. Consumers favourably choose brands that fit into their personality, or meet their personality aspirations.

In other words, people obtain or consume products not just for their utilitarian worth, but also to improve their self-concept through the symbolic meaning contained in them. As a result, customers attempt to internalize the brand's meaning. Brands may therefore aid in the formation of a person's self. The consumer's impression of the compatibility between the brand's identity, their own identity is connected to the function of self in consumer decision making. People look for businesses that have the same characteristics as them.

From these findings, it can be observed that brand personality literature has evolved beyond a point of simply recognizing the existence of a brand personality to one where scholars and managers alike are now interested in its practical and impactful implications. This research adds to the body of knowledge about brand personality by giving scholars a valuable tool for studying its effects. Furthermore, it is important to note that the brand personality dimension can be used to explore the effects of various branding strategies on consumer perceptions of brand personality, and resulting behaviour and decision making.

Apart from the contribution and importance of this paper, it is limited in the sense that, it focuses on a review of existing literature and does not consider empirical evidence to make its findings and conclusions. Hence, future studies should consider the empirical validation of the proposed model.

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FRAMEWORK OF DECISION MODEL FOR ROBOTIC GRIPPERS FOR ROBOTIC BIN-PICKING IN INTRALOGISTICS

Primož Bencak & Tone Lerher

Abstract

With the introduction of e-commerce and its requirements, a need for more advanced warehousing systems and storage methods has arisen. Order-picking has been faced with challenges concerning speed, reliability and lowering overall costs. The increasing introduction of robotics into logistics solved many of the above problems. However, to pick items efficiently and reliably, a proper robotic gripper must be chosen to pick items, that are various in shapes, colours, sizes, surface roughness, etc. This paper deals with establishing a framework for decision model to select the most suitable robotic gripper for robotic bin-picking in intralogistics, called Robotic Gripper Selection System (RGSS). An extensive literature review on the topic of expert systems and decision models for selecting the most suitable robotic gripper is provided. Next, a framework with recommendations about building such decision model is proposed. The most critical points of establishing RGSS are exposed and presented schematically, where each of the building block is presented in detail. The input of the proposed RGSS are object, hardware, environment, and application properties, which are used to calculate graspability success metrics using machine learning methods. A need for a fast and accurate automated measurement system is expressed. Based on the proposed framework, hardware, software, and an object set has been chosen to lay groundwork for future research work in PhD thesis.

Keywords: *e-commerce, robotic bin-picking, robotic gripper, decision model, expert systems*

1 INTRODUCTION

Logistics is becoming an increasingly important activity globally, with an estimated annual industry value of 5,582.58 billion € in 2018 (Statista, 2020). Intralogistics (internal logistics), including the warehousing process, is one of the largest activities in logistics, accounting for around 20.5% of the total logistics market, indicating the strong importance of intralogistics in the economy. Intralogistics covers all technical systems, services, and operations concerning the material and information flow inside of production processes. Processes in the domain of intralogistics are of key importance to managing material and information flow along the whole supply chain as they ensure reliable and predictable material and information flow (Nagel et al., 2008). With the growing trend towards e-commerce (Boysen et al., 2019), numerous different and individual (unique) items, short delivery times and variable (unpredictable) demand, a need for more advanced warehousing systems and storage methods has been created. More efficient e-commerce operations are made possible using modern warehousing strategies and the automation of transport with Automated Guided Vehicles (AGVs) and Autonomous Mobile Robots (AMRs) (Fig. 1) and Robotic Mobile Fulfilment System (RMFS) along with the use of modern robotic order-picking systems (Azadeh et al., 2019). It should be noted that the use of robot order-pickers requires the introduction of new transport and storage equipment, which significantly increases investment costs, but brings many improvements in the long run such as higher throughput, lower error possibilities, better working conditions (Cohen et al., 2021; Fager et al., 2020). In recent years, so-called "hybrid" order-picking systems have been developed, which means the cooperation of an order-picker and an order-picking (collaborative) robot (Azadeh et al., 2019; Jaghbeer et al., 2020).

1.1 Collaborative robots in order-picking

Due to the increasing use of collaborative robots in industry and their advantages, they are also being increasingly used for order-picking. Currently, the biggest challenge of robotic order-picking is to provide a system that can efficiently pick a wide range of items autonomously for production or e-commerce (Mahler et al., 2019). Due to the great variety of items (different dimensions, shapes, weights, etc.), this type of order-picking is a challenge for designers of advanced robotic grippers, the use of 3D machine vision and machine and deep learning algorithms. This area is currently being addressed by several international scientific research institutions, which are focusing their research efforts on the development of new algorithms for object recognition, determining the position and orientation of objects in boxes or crates (Liu et al., 2012), and developing algorithms for optimal object grasping (Mahler et al., 2019; Morrison et al., 2018; Pinto & Gupta, 2016; Spenrath & Pott, 2017) using various robotic grippers (Brown et al., 2010; Domae et al., 2014; Hasegawa et al., 2017).

Fig. 1 – A mobile robot with a mounted collaborative robot. Source: Adobe Stock (2021)

When introducing robotics into manufacturing and warehousing processes, business users (designers and operators of production and warehousing systems) are faced with the challenge of selecting the right robotic gripper, which, if selected correctly, can dramatically increase throughput and system reliability and reduce overall costs (Fantoni, Capiferri, & Tilli, 2014).

1.2 Selection of an appropriate robotic gripper

The selection of a suitable robotic gripper can be aided by personal (practical) experience, the use of different methodologies (Schmalz & Reinhart, 2014), recommendations and guidance from manufacturers (such as the Festo Gripper Selection software (Festo, 2021)), decision models or expert systems (Pham & Tacgin, 1992a) with a knowledge base and a set of rules that can be used to select a suitable robotic gripper. Expert systems are now being replaced by machine learning techniques, such as artificial neural networks, due to the limited range of complex problems that can be solved and the difficulty of formulating the problems. Based on the input parameters of the object (item) (physical properties and geometric shape of the item) and the process (e.g. order picking, assembly, inspection, etc.) to be performed by the robot, the system ensures the selection of the most suitable robotic gripper for the selected application. Of course, developing such a system involves a very large number of experiments with a wide variety of shapes and types of items and learning using machine learning methods. The upgrade of the robotic gripper selection system can also be used in conjunction with the automated warehousing system for a more efficient order-picking process.

The subject of the paper is a framework for development, design and learning of a complex decision model, called Robotic Gripper Selection System (RGSS). RGSS will be able to select/predict the most appropriate robotic gripper for the picking, assembly and sorting process concerning items stored in an automated small parts warehouse system with high accuracy.

2 LITERATURE REVIEW

One of the first attempts to provide a framework for selection of the most suitable robotic grippers, was by Erdman et al. (1986). The authors of the paper propose a process for selecting the most appropriate robotic gripper to help select a suitable kinematic topology. Pham and Yeo (1988a) analyse the factors that are important in a robotic gripper selection process. These are factors relating to (1) the object (item) to be analysed, (2) the task to be performed, (3) the working environment, and (4) the robot with the gripper. Decision guidelines are given to support the decision on which surfaces of the item to grip, how to grip the item and which standard robotic gripper to use. In another paper, Pham and Yeo (1988b) present the design of an expert system based on the factors described above. Although in a simple text format, the expert system allowed to solve quite complex decisions on the choice of a robotic gripper and to learn from experience. Followed by Hesse and Mansch (1989) their paper deals with the selection of flexible robotic grippers, which is based on computer-aided technologies. Pham and Yeo (1991) presented a strategy for reducing the number of different robotic grippers needed. The presented expert system allows choosing between jaw, vacuum, and magnetic robotic grippers. The selection of a robotic gripper is based on the outcome of how efficiently the item is grasped, how to grasp it and which type of robotic gripper to use. The expert system considers the parameters of the object properties, specifications of the process, compatibility of the robot and the number of surfaces of the item to be gripped. Pham and Tacgin (1991) present an expert system for the accurate selection of commercially available robotic grippers, which considers four groups of article characteristics: physical properties, surface, geometry and additional properties. Surface properties affect the gripping coefficient, jaw material and maximum gripping pressure, while material porosity affects the ability to provide vacuum. Pham and Tacgin (1992a, 1992b), deal with accurately identifying and selecting the most suitable commercial robotic gripper for the robotic bin-picking process. Agrawal et al. (1992) presented a methodology for the evaluation and selection of the most suitable robotic gripper in flexible manufacturing systems, based on multi-criteria decision model, called TOPSIS. Their model allows the assessment of individual properties, while the final decision on the most suitable robotic gripper is still up to the end-user. Pedrazzoli et al. (2001) propose the use of six phases for the selection of a robotic gripper, namely: 1. selection of the finger type, 2. finger sizing, 3. selection of the gripper morphology, 4. determination of the necessary gripping force, 5. constraints on the choice of the gripper, 6. determination of the actuator (electric, hydraulic, etc.). For each selection stage, rules or recommendations are given, such as an expression for calculating the necessary grip force for a specific grip of an item. In their work, Fantoni, Capiferri and Tilli (2014) present a more advanced implementation of the development of an expert system for robot gripper selection. They conclude, that the choice of a robotic gripper also depends on the feeding conditions, the behaviour of the item during manipulation (e. g. compressibility), the location and the drop conditions of the item (especially in the case of breakable objects). A set of rules that guide the user through the process of selecting the most appropriate gripping principle is proposed. A comprehensive database of robotic grippers with examples from industry and research is also provided. They conclude, that a comprehensive approach that would allow the designer of robotic systems to efficiently select the appropriate robotic gripper in the case of objects (items) with different dimensions, characteristics and handling constraints still does not exist. Fantoni et al. (2014) published a review article, which

provides a comprehensive overview of robotic gripping technologies used in various areas of automated processes, including logistics. In their work, Schmalz and Reinhart (2014) present an automatic gripper selection approach that combines economic, flexible and functional selection criteria. The weaknesses of robotic gripper selection methodologies of that time and proposals for a more efficient expert system for robotic gripper selection are presented. The authors stress the importance of developing such a system, as the robots in the future will decide for themselves which robotic gripper should be used for a specific task. Fujita et al. (2019) highlight the importance of the challenge of bin-picking and the importance of using multiple robotic grippers to grasp different objects (items). They note that the appropriate choice of the combination of robotic grippers depends not only on the variety of items but also on the sparseness of objects inside bins. Mahler et al. (2019) introduced the Dex-Net (Dexterity Network) platform which enables the selection of a grasping strategy on different robotic grippers on virtual models using analytical models. Their platform is based on machine vision data and prior learning from convolutional neural networks (CNNs). CNNs learn to classify objects of items that can be grasped using two-finger and vacuum robotic gripper. The robot, which has two robotic arms with a vacuum and a two-finger gripper, ensures that random items in the bin that have not previously been used for neural network training, are gripped with more than 95% accuracy. The uniqueness of their platform is that it only learns how to grasp objects from the simulation, not from the real environment. Azim et al. (2019) conclude that universal gripping solutions in the order-picking process can allow a wide variety of items to be gripped and save costs on a long-term basis. A methodology for designing a universal gripping solution for specific use cases is presented, focusing on the order-picking process. Salunkhe et al. (2020) propose a systematic way to identify robot gripper requirements in a collaborative robot application. The proposed methodology considers (1) the task the robot performs, (2) the number of components required for the assembly, (3) the Design For Assembly Analysis (DFAA), (4) an analysis of the process the robot is performing and (5) the requirements of the operator working with the collaborative robot.

We conclude, that between 2001 and 2014, there have been no major improvements in the field of expert systems or decision models for selecting the most suitable robotic gripper. In the early days of research, systems were based on textual data input (e. g. the surface is smooth, the material of the item is ferromagnetic, etc.) that were linked to databases of available robotic grippers. In the last few years, the development of collaborative robotics, machine vision systems and artificial intelligence has led to the development of complex and efficient robotic order-picking systems, which already incorporate expert systems or decision models for the most suitable selection of the robotic gripper. However, there is still a lack of tools that comprehensively address the selection of the most appropriate robotic gripper for a robotic order-picking application.

3 METHODOLOGY

In the following paragraphs, the methodology for establishing proposed framework for selection of most suitable robotic gripper is presented. On Fig. 3, a flowchart is provided, summarising all the important framework steps.

First, an overview of the research field must be provided, describing the suitability and relevance of work in the field of expert systems and decision models for the selection of a robotic gripper. Findings of selected relevant works need to be summarised using the compilation method. Systems, used to select the robotic gripper that have been described in former works, must be analysed, exposing important findings and shortcomings. Using the

abstraction method, extraction of irrelevant parameters and system parts in the problem of expert systems and decision models must be provided.

Next, an appropriate physical system for the experiments must be chosen. That includes robot, vision system and appropriate robotic grippers, which are representative in industrial settings as well as compatible with the selected robot. Of course, robotic worktable and accessories are a part of the robotic cell. A collaborative robot is preferred, due to the ability of working alongside of human operator. However, one must note, that for the robot to work in collaborative mode, several protective measures must be taken, such as installing safety laser scanner in the robot working range.

Next, choosing appropriate items for order-picking is a crucial step. Several object and model sets already exist in the scientific community, which should be more or less representative of the field they are used in (Calli et al., 2015; Leitner et al., 2017; Morrison et al., 2020). An example of object set is shown in Fig. 2. However, we recommend that the selection of objects is done based on the analysis from practice (industry collaboration) and composing inventory of items by weight, colour, roughness, physical dimensions, classification into groups must be done. 3D scanning could also be beneficial in form of digitalising the physical objects and including that information in decision model.

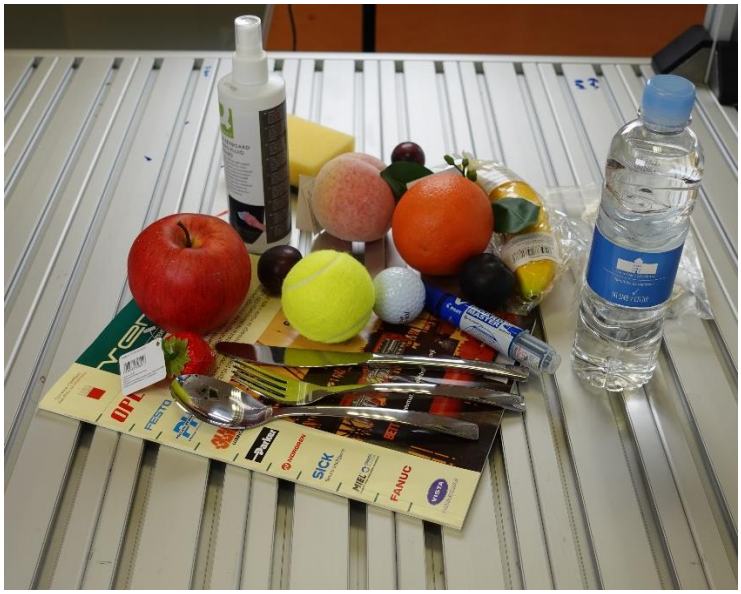

Fig. 2 – Some of the objects from our own object set. Source: own research

To speed up the process of determining the graspability success, a system for automatic item analysis should be developed. That includes development of an automated measurement system, using machine vision and algorithm for grasping point generation for collaborative robot. Based on the real-world measurements, data of graspability metrics must be stored into the database, saving robot gripper positions along with graspability success metrics. An exact protocol of the measurements must be prepared and carefully followed to ensure repeatability. Additional findings and problems should be documented alongside. Next, relationships between input parameters, robotic gripper and gripping performance must be found. Finding a mathematical function, that will model the gripping performance concerning the input parameters should be done with machine learning methods. Selection of an appropriate programming tool is therefore crucial to test and perform learning on different types of machine learning methods. Lastly, the model must be validated on known items for decision model and prediction model for unknown items to select the most suitable gripper.

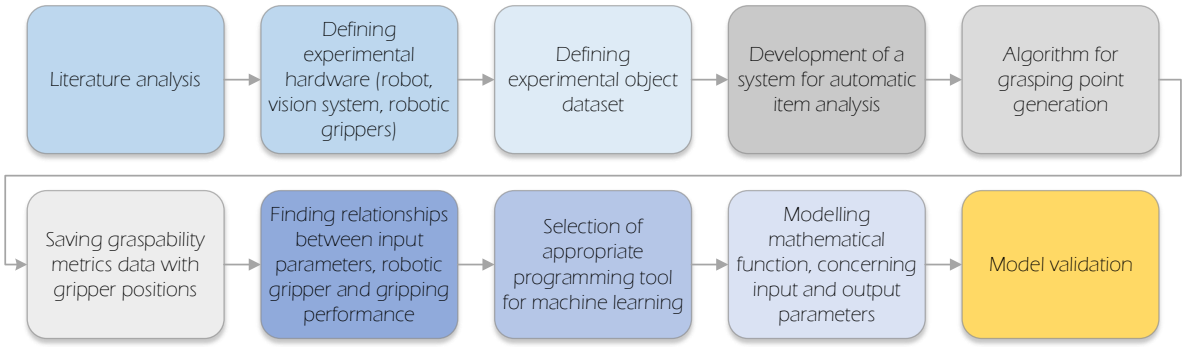

Fig. 3 – Flowchart of the proposed framework. Source: own research

Following the above methodology, specific recommendations for our research work have been developed.

4 RESULTS

Using the proposed methodology and the provided literature review, we have established an experimental robotic cell, based on the collaborative robot UR5e, shown in Fig. 4. Four types of robotic grippers have been selected – two-fingered mechanical gripper, vacuum gripper with variably-sized suction cups, gripper based on adhesive forces (e. g. Gecko) and soft-gripper, which is by itself designed for picking rigid and variably-rigid objects. Additionally, an automatic tool changer has been selected, which will provide faster tool changes. A 3D vision system, based on structured light has also been selected, which will lead the process of automatic bin-picking. Additionally, 2D camera for object measurements will be installed above the area of experiments. Several software tools will be used – LabView will be used for extracting physical object properties obtained from 2D camera, MATLAB/Simulink will be used for selecting and training appropriate machine learning methods on available datasets and MS Excel for general data input. Major focus will be put on neural networks as they seem most appropriate for our task. A user interface built in Python language will provide the end-user to add additional items into the decision model.

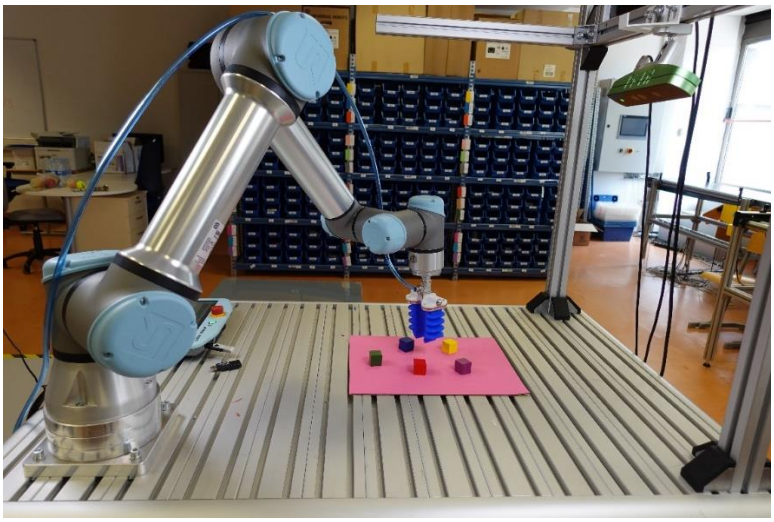

Fig. 4 – Robotic cell for the robotic order-picking process with UR5e collaborative robot and Pickit 3D machine vision system, where tests will be carried out to evaluate the performance of the RGSS system. Source: own research

The system will be initially tested on YCB object and model set (Calli et al., 2015), which provides us with the selection of various objects of different shape, size and other physical properties. Due to the export-import duties and high costs associated with the original object set, several items will be replaced with their counterpart, available in our local area. In the next step, we will select items, that are commonly represented in various industry types of smaller parts, such as automotive, robotics, etc.

Based on the above framework, a block diagram of RGSS has been prepared (Fig. 5), which describes input and output data of the decision model.

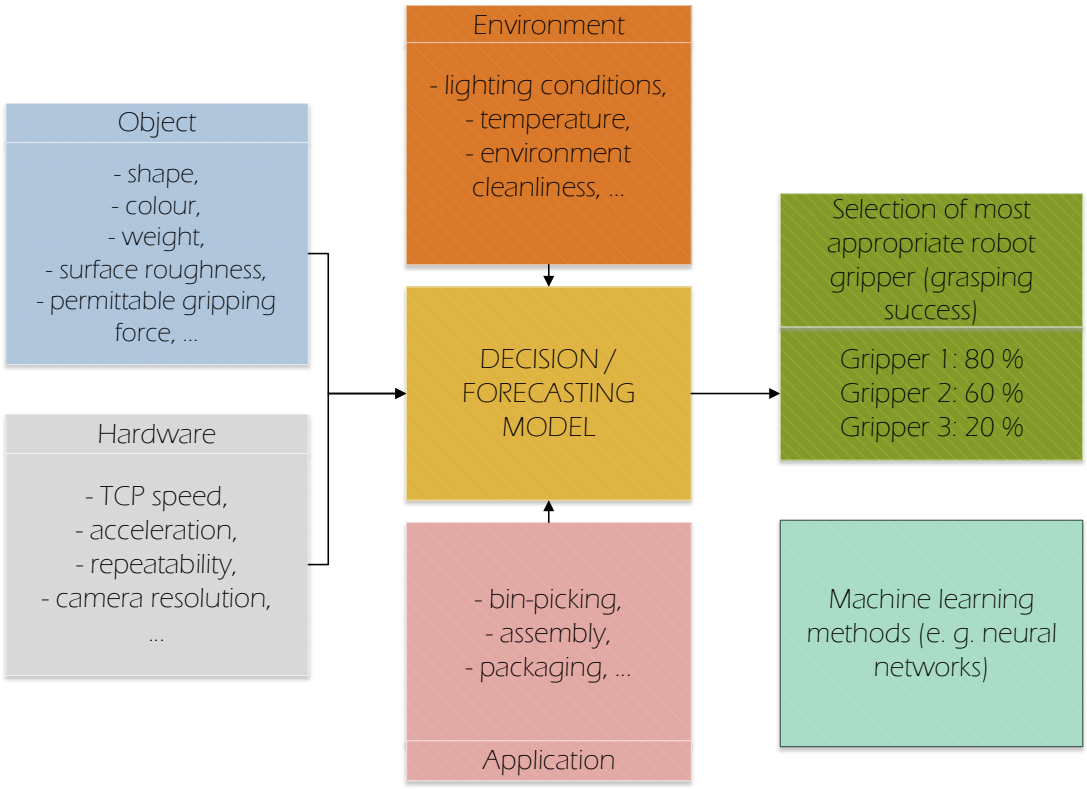

Fig. 5 – RGSS block diagram. Source: own research

The input of the decision/forecasting model comes from several data sources – the object in question and its physical properties (shape, colour, weight, surface roughness, maximum permittable gripping force, etc.), hardware used (collaborative robot, vision system), application and application environment. The selection model will be taught using machine learning methods, preferably neural networks. The output of the selection model is the percentage of suitability (success rate) for certain robotic gripper, e. g. for object 1, the vacuum gripper is 80% likely to pick up certain object, object 2 is 40 % likely to be picked up with two-fingered gripper, etc. The percentage of gripper success rate will be determined based upon physical experiments, which will be performed in various pick points and under different environmental variables, described above.

5 DISCUSSION

An extensive literature review provided us with the information needed to specify the requirements for decision/forecasting model for most suitable robotic gripper for robotic bin-picking application in intralogistics. A framework for the decision model of selecting the most appropriate robotic gripper for robotic bin-picking in intralogistics has been proposed, which will lead the following research. It is of great importance to properly specify the direction of

research work in the planning phase, as it can drastically reduce the time needed to complete the study and prevent possible problems. Our current work has been focused on selecting the most appropriate hardware, which is also commonly used in industrial setting, proving useful there without major modifications. A lot of effort has also been put in selecting the most representable object and model set, which will guide the direction of the research. The proposed framework is, however, only a recommendation and can be freely adapted to meet specific needs or analyse specific scenarios.

6 CONCLUSION

The proposed framework serves to guide researchers, interested in robotic bin-picking. Selecting the most suitable gripper for specific type of products can be a challenging task, especially where high throughput and accuracy is required. Commonly, a combination of two-fingered gripper and a vacuum gripper is used in complex bin-picking scenarios, but that is not always the best configuration. Therefore, decision models for the most suitable robotic gripper are invaluable tools, which can not only guide fixed robotic bin-picking stations, but also AGV- and AMR-assisted robotic order picker. The main challenge associated with the RGSS is establishing an automated measurement system, capable of fast and reliable data acquisition. Performing manual tests are namely very time consuming, not to mention strenuous and difficult to analyse. Next, the automated measurement system must be connected to the collaborative robot interface (control box) which poses another challenge. Therefore, future research should focus on providing a whole automated measurement system which would be able to provide efficient and correct data. Lastly, several new datasets could be provided, which are used in different types of industries. This way, RGSS could be adapted to meet specific industry needs.

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METHODOLOGY OF DESIGNING ROBOTIC WORKPLACES USING AUGMENTED REALITY ENVIRONMENT

Róbert Bočák, Radovan Holubek

Abstract

The aim of the article is to clarify the use of modern technology by displaying in the Augmented Reality (AR) environment. The goal of using AR is to extend the real environment using a suitable display device (smartphone, tablet, glasses) and appropriately selected software for creating a virtual environment with digital 2D/3D objects. Based on the use of AR technology, the user obtains a comprehensive idea and visualization of future machines and devices, taking into layout solution of automated workplaces in a real environment. The research article focuses on the possibilities of implementing and visualizing the change of another type of robot in a real robotic workplace – iCIM 3000. The result will be the creation of an AR application in the Vuforia Studio software. The resulting AR application will focus on the possibility of visualizing the extension of a real assembly robotic workplace of the iCIM 3000 system with other kinematic structures of industrial robots with visualization of their range and workspace. The application itself will consist of several kinematic structures of serial kinematics of industrial robots. At present, the real assembly robotic workplace iCIM 3000 has a 6-axis angular industrial robot Mitsubishi RV-2SDB. The real workplace will be extended and visualized by the AR application with the SCARA robot ABB IRB 910SC, the collaborative SCARA robot Precise Automation PF3400 and the angular robot KUKA KR3 Agilus. The display of the resulting AR application will be realized using a smartphone and a visualization application for AR display Vuforia View.

Keywords: *simulation, augmented reality, robot, workspace, iCIM 3000, Vuforia Studio*

1 INTRODUCTION

Nowadays importance of increasing productivity and effectivity of production systems is increasing rapidly. Companies all around the world use various tools to achieve and improve these properties and parameters. One of these tools is Augmented reality environment. It is a suitable way, how to visualize and modify existing production systems in virtual environment with no need of complex 3D CAD data of entire production system. In many cases, old production systems don't have 3D CAD data or there are only few parts created in CAD. AR offers allows us to visualise digital data, which can't be commonly seen such as workspace. Another useful way to use AR is in innovation process, where we can check suitability of new device, its dimensions and correct placement without harmful interference to production systems or to own real device. Visualisation can be done even when production system is running.

In our case, we want to innovate existing robotized assembly production system iCIM 3000 (Fig. 1). iCIM 3000 consist of two NC control milling machines, station for quality control, assembly station and automatized storage. All these parts are connected by transport system and operated by three industrial robots Mitsubishi RV-2SDB (Holubek et al., 2013). Innovation is realized by exchange of industrial robots by robots with different kinematics structures. As a visualisation tool for AR environment, we created mobile application in Vuforia Studio, which able us to see three potential options (ABB IRB 910SC, Precise Automation PF3400 and KUKA KR3 Agilus) and help us to choose best option for our purpose. This mobile application

use function to connect 3D CAD model with real robotic arm in ratio 1:1. It also dispone with work area of selected robots.

Fig. 1 – Robotized assembly production system iCIM 3000. Source: own research

2 THEORETICAL BACKGROUND

AR technology is technology, which integrates virtual and real-world information. It makes extensive use of various technical means such as 3D modelling, real-time tracking, interaction with virtual information such as 3D models, images, computer-generated text, video or music and applies them into a real world (Duan, 2021). This is one of ways how to combine real and virtual environment (Jeffri & Awang Rambli, 2021). This technology helps to improve conceptual understandings of users' spatial and cognitive abilities and control emotions (Jung et al., 2021). Basic characteristics of AR systems are (Bellalouna, 2021): (a) Interaction in real time – user uses hand gesture, touchscreen, earphone or microphone to interact with real and virtual objects and data in real time. (b) 3D visualization – 3D visualization must be connected to the user to follow motions and positioning according to 3D objects placed in virtual space. (c) Combination of reality and virtuality – using sensors such as camera or gyroscope allows to detect orientation according to scanned object. Based on perspective view and user position, virtual object is rendered in correct geometric orientation and size.

The aim of using AR systems is to improve information and perception of real world. This can be achieved by connecting digital knowledge appropriate to the environment. Knowledge can be visual, haptic or auditory. AR systems are divided to the two groups: mobile and fixed. We can also divide it into wearable (helmets, glasses) and non-wearable devices (smartphone, tablet, PC) (Yavuz et al., 2021).

In present, almost every mobile device is able to run AR technology. New sensors, displays and faster internet connection are only a few reasons, why AR is booming since 2010s. These devices are commonly limited to handheld mobile devices. Recent developments and announcements of state of art technologies companies predicts that, once AR technology becomes integrated into mobile devices and users can operate it with free hands, AR will experience breakthrough in the market. Companies like Microsoft, Apple or google already started to develop these devices (Rauschnabel, 2021).

When comparing AR and virtual reality (VR) technology, AR has two main advantage – better interaction and better sense of reality. VR simulates surrounding environment which becomes "real world environment" to make user feel more immersed in it (Yavuz et al., 2021). AR users are not isolated from real world. They still can see physical environment around them but the AR technology enhances it with virtual data. Some manufacturers are using term "Mixed reality" (MR) to point out integration of 3D elements into user's perception of real world and "assisted reality" mainly used for applications focused only to contextual information (Rauschnabel, 2021).

Nowadays, there are many of software development kits (SDK) which enable us to create mobile AR application such as Vuforia, Wikitude, ARToolKIT, Metaio, ARmedia or D´Fusion. All of them are free, but they have differences in supporting platform, marker generation, type of tracking, overlaying capability etc. (Amin & Govilkar, 2015)

We can find usage of this technology in various different fields such as education, medicine, architecture, marketing, maintenance, training and assembly process. In industry is AR presented as a tool for improving flexibility and process efficiency. Even lot of studies agree that AR has many benefits in various industries, its actual use is not repeating. (de Souza Cardoso et al., 2020)

3 METHODOLOGY

Mobile application was created in Vuforia Studio software. It is a platform that helps users create, deploy and utilize powerful augmented reality experiences. These AR experiences can be viewed through smartphones, tablets or wearable devices.

Comparing to another AR SDKs Vuforia has cloud databases which enables us to create thousands of image targets. On the other hand, device database can contain only a 100 image targets. Other advantages are online target manager, tracking 3D objects or various types of markers (Frame marker, image target, text target, spatial target).

Software environment is divided into two main sections:

2D section (Fig. 2) – was used for 2D application environment layout. In this section we set all the buttons preferences such as shape, colour, text font and size using JavaScript. After buttons were set, we programme it to show and hide selected objects.

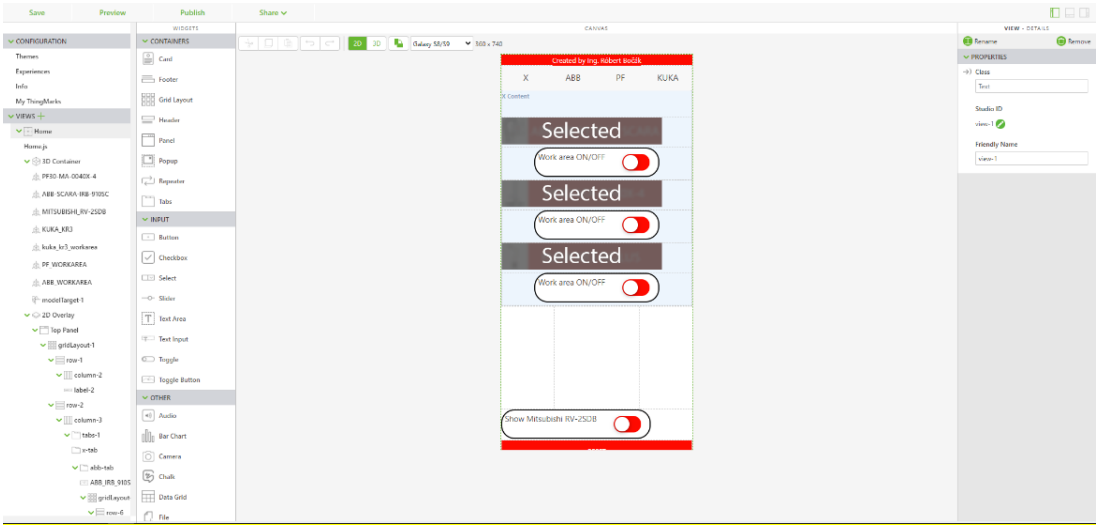

Fig. 2 – 2D section. Source: own research

3D section (Fig. 3) – was used for work with 3D models, thus modify their scale, positioning, transparency etc. Another function is set targeting real object for matching with 3D model. We set optimal contour of robotic arm for fast recognition.

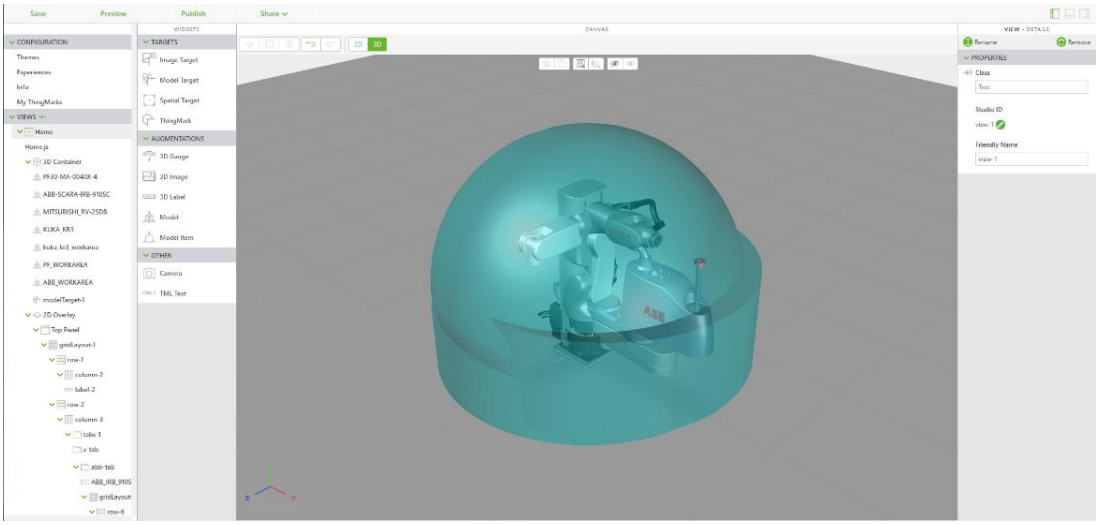

Fig. 3 – 3D section. Source: own research

Robot models were downloaded from official website of supplier and then uploaded into Vuforia software. These models don't contain their work areas. We had to create it manually according datasheet for every robot. Work areas were created in Siemens NX software (Fig. 4).

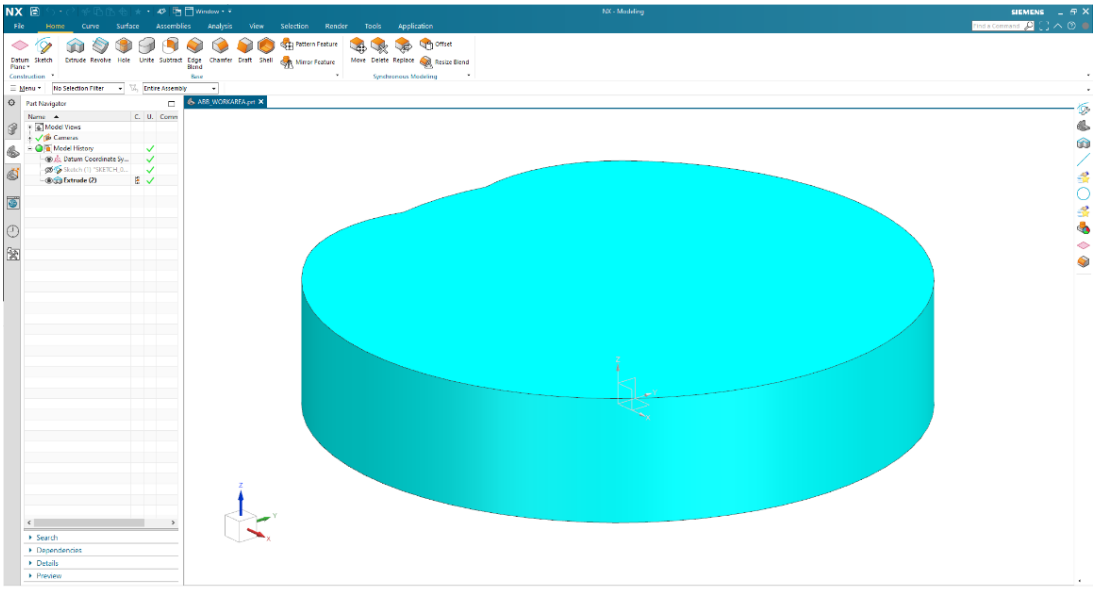

Fig. 4 – 3D section. Source: own research

4 RESULTS

The result of this paper is created mobile application (Fig. 5), which able to see different robots with their work areas instead of original one Mitsubishi RV-2SDB to upgrade production system iCIM 3000.

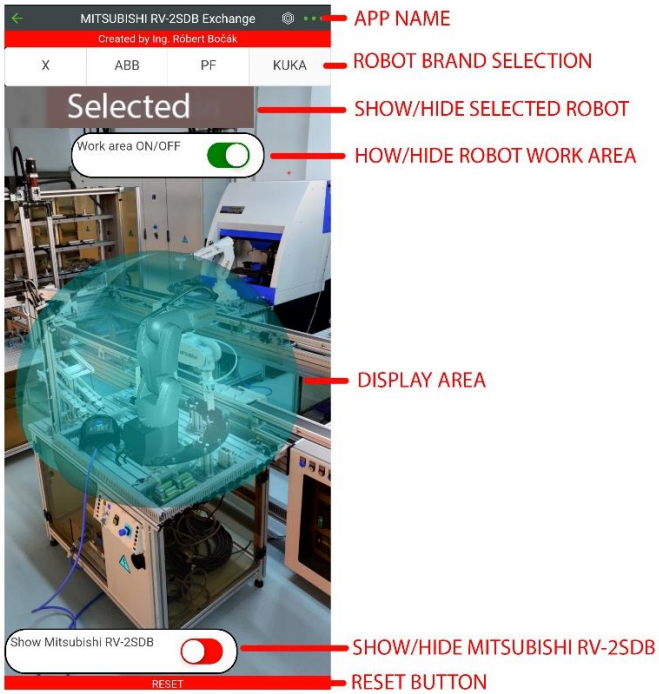

Fig. 5 – Application environment. Source: own research

Application allow user to choose from three different brands of robots – ABB (Fig. 6a), Precise Automation (Fig. 6b) and KUKA (Fig. 6c). Each brand offers to choose one robot from their portfolio, which could replace current robot. It also allows to show or hide their work area, thus user can see if the robot is suitable for work.

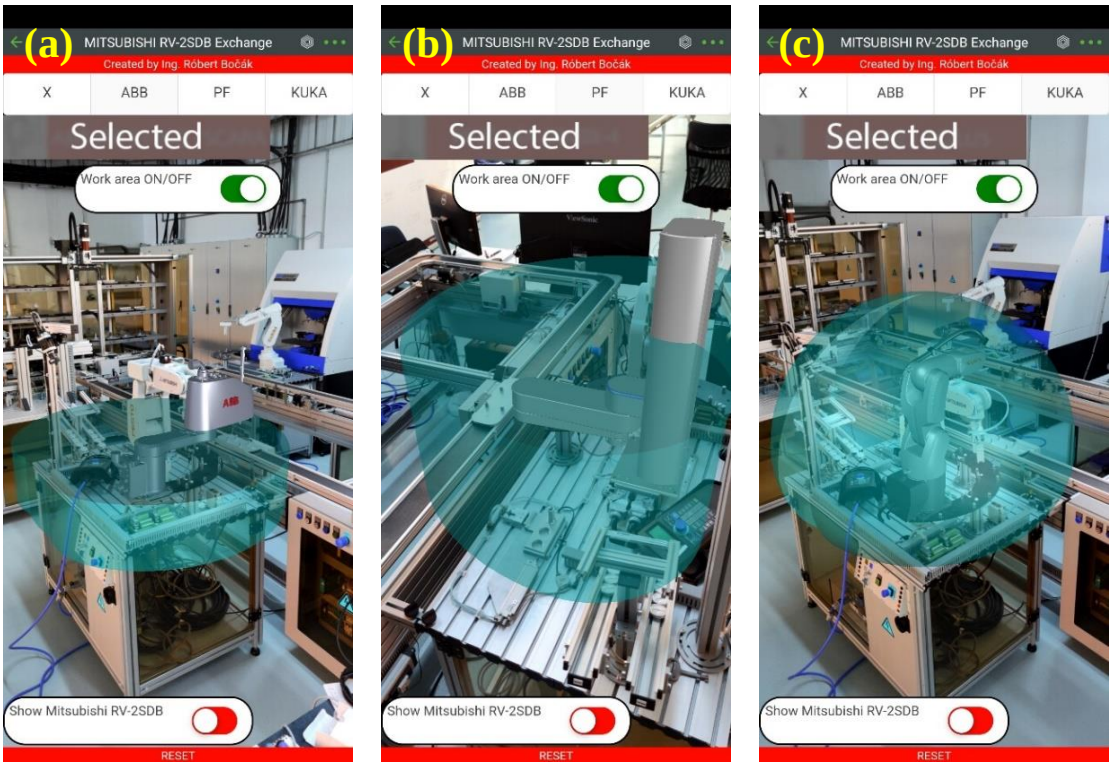

Fig. 6 – ABB IRB 910SC (a), Precise Automation PF3400 (b), KUKA KR3 Agilus (c). Source: own research

First step is to match robot contour with real robot (Fig. 7a) to make connection with 3D CAD model and real industrial robot (Fig. 7b).

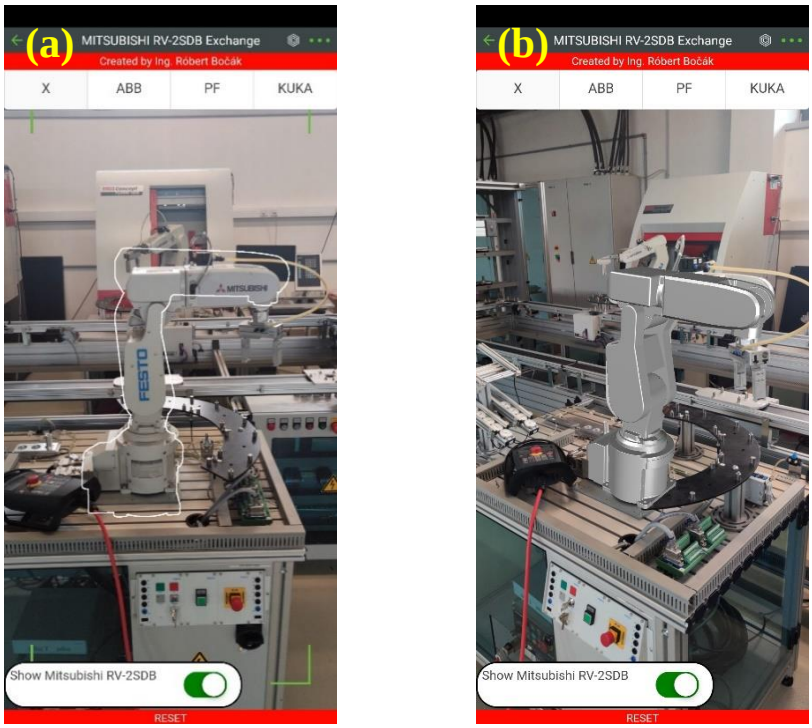

Fig. 7 – Matching CAD model with real robot. Source: own research

When application recognize the shape of robot, 3D model is attached on real robot and user is able to walk around and see 3D model from every angle. Thus, evaluate if the robot is suitable for work and if the new robot needs to be placed on the same or different place to be able do its work. After that, user can switch robot 3D models in application with their work area and compare it between themselves to choose best option for production system.

5 DISCUSSION

Using the created application interface in the Vuforia Studio software for augmented reality, it was possible to create an AR application, which had the task of implementing and visualizing other types of industrial robots in the real working environment of the assembly robotic cell of the iCIM3000 system. The aim of creating the AR application was to visualize three different kinematic structures of industrial robots with regard to the rendering of the work area, based on the display of the study using the Vuforia View application, which is intended for displaying AR applications in smartphones or tablets. Most common method of creating this type of AR application is to create 3D objects using Unity3D software which are then used in Vuforia Studio. Our method was to create 3D objects in CAD software Siemens NX, which does not require knowledge in programming.

The first robot used, which could be displayed in an AR application, was the SCARA robot ABB IRB 910SC (Fig. 6a), has a kinematic structure formed by a rotary-rotary-translation (RRT) arrangement. The second was used unique collaborative SCARA robot Precise Automation PF3400 (Fig. 6b), whose kinematic structure is formed in the translation-rotary-rotary (TRR) concept. Thus, it is a different type of arrangement of the kinematic structure of a SCARA robot. In the third place, an angular industrial robot KUKA KR3 Agilus (Fig. 6c) was used, whose kinematic structure is formed by rotary-rotary-rotary (RRR) arrangement of kinematic pairs. These robots were conceptually selected based on: (a) Consideration of the size class of the robot; (b) Verification of the reach of the selected robots with regard to the current handling operations performed by the real industrial robot Mitsubishi RV-2SDB; (c)

Consideration and rendering of the working space of selected robots with the possibility of displaying in the AR environment; (d) Choice of robot parameters (applicability to selected handling operations, accuracy class, speed, range, price).

6 CONCLUSION

Based on the visualization of the study, it can be stated that the use of AR technology is a very good tool for visualization in the preparatory phase of innovative procedures of planned changes in existing workplaces without the need interfere and affect the functionality of the real workplace. By displaying the created study (Fig. 8) in AR applications, we were able to quickly visualize and validate possible changes to the replacement of an existing robot with another type. We also immediately saw the rendering of the work area, which is intuitively shown in the displayed AR application with the ability to switch between individual robots and their workspace. Ultimately, the use of AR technologies appears to be a very good and suitable tool today, when by using minimal investment costs and no need to have high-performance computers, it is possible to create AR studies with appropriate software support.

Fig. 8 – QR code for created study. Source: own research

6.1 Future research

In the future, the authors of the article are considering expanding the research by supplementing the database of several industrial robots, also with the implementation of the kinematics of the motion of the selected robot.

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THE ANALYTIC HIERARCHY PROCESS AS A METHOD TO DETERMINE THE APPROPRIATE METHOD OF SELECTING EMPLOYEES IN INDUSTRIAL ENTERPRISES IMPLEMENTING INDUSTRY 4.0

Lucia Cuninková, Eliška Kubišová, Miloš Čambál, Dagmar Babčanová

Abstract

We are currently living in the time of the fourth industrial revolution, the so-called Industry 4.0, which significantly affects the functioning of companies and their employees. The labour market is undergoing major changes, especially in the field of working conditions and requirements on employees, new positions are emerging that companies have not yet encountered but must incorporate them into their organizational structures as a necessary step in their further functioning. Human resources professionals are placed in the difficult task of filling these positions with qualified employees who will perform the best possible work and bring the greatest benefit. All changes Industry 4.0 has caused in terms of job requirements on employees affects recruitment of every industrial enterprise The aim of this paper is to determine the appropriate method of selecting employees in industrial enterprises according to requirements of Industry 4.0. The main goal of research is to apply multicriterial decision-making method - the Analytic Hierarchy Process method to choose appropriate method of recruitment of qualified employees for newly created positions that arose during the implementation of Industry 4.0 in industrial enterprises. In the last part of the paper presents results of research focused on analysis of selected existing methods of recruitment using Expert Choice software, with the aim of suitability for implementation in industrial companies that are currently implementing Industry 4.0. The Analytic Hierarchy Process method determines the most appropriate method for recruitment of qualified employees well-known Assessment Centre, which allows the inclusion of a wide range of factors affecting the performance of work. However, it is necessary for the future to determine the more precise changes that companies have to make in the field of selecting employees and whole human resources processes as well.

Keywords: *Analytic Hierarchy Process, Competencies, Industry 4.0, Labour market, Job description, Job requirements, Recruitment*

1 INTRODUCTION

Never-ending constant changes, this phrase perhaps best describes the current situation not only in the labour market. Every day something new is coming, something that surprises the world. It is assumed that the most influential factor of industrial and subsequently socio-cultural change is development technologies. The current capacity to use energy resources, transport and communication infrastructure and information sharing is huge. The ongoing dynamic evolution of technology has a very strong influence on the development of society, which is reflected in the labour market, the structure of qualification needs and the growing importance of new types of responsibilities and competencies, which also increases the importance of optimal conditions of human capital. New technologies, procedures, approaches, ways of thinking and solving various problems, when added to the influence of the human factor, we have something here that could act as an insoluble problem and an incompatible combination at the same time. Although interpersonal relationships are very complicated and any activities that affect human resources are mostly in some way influenced by the subjective view of the

solvers of these issues, we still think that it would be curios to look at the issue from the perspective of hard science and try to suggest the most crucial and critical answer to questions in the field of HR and that could be how to select the best employees and gain a competitive advantage in the market. The aim of this paper is to determine the appropriate method of selecting employees regarding emerging positions in industrial enterprises implementing Industry 4.0 using multicriterial decision-making method.

2 LITERATURE REVIEW

Digitization, automation, the Internet of Things, machine learning, artificial intelligence and much more. These are the key concepts of today. In 2021, 10 years have passed since the first mention of the term Industry 4.0 (Vereycken et al., 2021; Demir et al., 2019).

If we look at the history of how the individual industrial revolutions developed, the first industrial revolution was started by the invention of the steam engine and is characterized by the transition of some activities from manual work to mechanization of production (Wojčák et al., 2018). The second industrial revolution can be dated to the beginning of the 20th century, and we consider the invention of electricity and the telegraph to be a key turning point, which enabled the use of electricity and belt production to create series production (Richnárik & Sarmány, 2019). The third industrial revolution marks the development of computer and communication technologies, the so-called the beginning of the information age in the 70s of the 20th century and is characterized by automation. The time between the emergence of the following revolutions is shortening, and as early as the middle of the 20th century, the Fourth Industrial Revolution came to us, connecting the physical world with the virtual and is therefore called the digital revolution (Speringer & Schnelzer, 2019; Schwab, 2016).

We are currently living in the time of the fourth industrial revolution (Richnárik & Sarmány, 2019), which fundamentally changes the way we live, work, and communicate. The revolution is about connecting billions of people by mobile devices, with unprecedented computing power, data cloud capacity, and access to information and knowledge, which have almost unlimited possibilities. This information is amplified by constantly emerging new technical inventions in various fields, such as artificial intelligence, robotics, the Internet of Things, autonomous vehicles, 3D printing, nanotechnology, biotechnology, quantum computing, etc. The digital and physical worlds are connected, which means that all activities are irreversibly connected to machines, systems, and to people who can share information and try to adapt automatically (Wilkins, 2020). The ability to take advantages while reducing disadvantages that new technologies could bring will also depend on the adaptability of the labour market (Kergroach, 2017). Currently, all companies must cope with the fact that constant technological changes are one of the main factors influencing the labour market, skills, demand, and the structure of occupations. So far, it has not been precisely defined what the HR department should look like at the time of the fourth industrial revolution, there are no exact procedures of the so-called HR 4.0, which would be able to answer all the questions concerning the relationship between HR and Industry 4.0 (Dohale & Kumar, 2018). Which could mean that the levels of the impact of Industry 4.0 on human resources and thus the labour market are constantly changing, and it is difficult to define it from one point of view (Piccarozzi et al., 2018).

2.1 Impact of Industry 4.0 on the labour market

The digitalisation of the economy and Industry 4.0 offer new opportunities and challenges (Wojčák et al., 2018). New technologies can generate increased productivity and facilitate market transactions, creating new goods and services with almost zero or zero marginal costs. In addition, these changes and new technologies have major implications for the labour market,

they can create new jobs and occupations, but at the same time they are threatening some of them. The introduction of new technologies in companies will change the nature of work and the structure of the profession, which significantly changes the value of people's skills their importance in creating job positions (Ejsmont, 2021; Herceg et al., 2020).

Demand for physical, manual skills is expected to decrease, and with them some routine activities and processes, as well as social and emotional skills and cognitive abilities, as well as logical thinking, and whether creativity will grow rapidly in job requirements (Manyika et al., 2017). Several studies require that 45% of jobs focused on manual work, can be cancelled due to automation and digitization while automation and digitization alone bring a maximum of 5% of new positions (Choi, 2017). This is confirmed by the close connection between Industry 4.0, and the level of knowledge and skills of employees, and the fact whether work is routine or not. Currently, most studies require less impact of Industry 4.0 on the labour market with the qualified employees (Makhoul, 2018; Závadská & Závadský, 2020). Unstoppable technological development reflects primarily in the change of the work environment, in working conditions and especially in the required employees' skills that affects work performance (Pajtinková Bartáková et al., 2017; Bendová, 2020).

Change of environment

Digitization exceeds traditional company boundaries, creates global value chains, and also affects job geography. Technologies are entering the industry and expanding digital platforms into production processes (Davies et al., 2017). There are new business models with the ability to quickly develop from small businesses - called start-ups into huge global giants. It can be stated that also with a small number of employees or smaller assets, digitization allows people to create a group of different companies also in less developed industrial fields (Rotman, 2013).

Change of working conditions

Frey and Osbourne (2013) assume that the character and way of work in Industry 4.0 pressures companies to be more accessible and flexible. Standard types of employment contracts often change to shorter-term project or order contracts, which are also implemented through online work platforms (Autor et al., 2013). It causes the emergence of new work platforms, formats and there are formed new workgroups, teams, and working conditions.

Change of required employees´ skills

The most significant and the strongest changes caused by the fourth industrial revolution are reflected in the requirement of employees who enter the labour market. Jobs with routine activities are slowly reducing, and otherwise, skills that cannot be replaced are coming forward. New jobs are being created. In addition to standard requirements, new jobs require a certain level of technical competence, strong computer skills, strong organizational and communication skills (Benešová & Tupa, 2017; Ananiadou & Claro, 2009), but also specific requirements (Motyl et al., 2017; Fareri et al., 2018; Kipper et al., 2021) such as critical thinking, ability to interact with new modern interfaces, emotional recognition, and management for better coordination of work teams, extensive expertise in several fields and advanced knowledge of the world language, which is currently English.

2.2 Qualified employee recruitment methods

Newly created positions will require qualified candidates who must have specific requirements for the work performance from the point of view of professionalism and personality traits (Pinzone et al., 2017; Hitka et al., 2016). Companies and their human resources departments have several employee selection methods. However, the managerial decision to determine one of employee selection methods itself will not be easy because each method considers and

evaluates different characteristics. The most common methods are (Majtán, 2003; Armstrong, 2007; Koubek, 2007; Šimko, 2019): professional competences tests, personal interview, assessment centre, professional skill tests, and personal questionnaire. Therefore, due to time and cost requirements, companies prefer to choose one of the most suitable methods which would provide them the best possible result.

3 METHODOLOGY

We used several research and statistical methods to achieve the goal of this paper. We primarily used the analysis of current scientific research publications, multicriteria analysis with pairwise comparison and confronted individual expert opinions on the issue with their own conclusions. The aim of this paper is to determine the appropriate method of selecting employees in industrial enterprises according to requirements of Industry 4.0. Which is directly related to the main goal of research is to apply multicriterial decision-making method - the Analytic Hierarchy Process method to choose appropriate method of recruitment of qualified employees for newly created positions that arose during the implementation of Industry 4.0 in industrial enterprises.

3.1 Multicriteria analysis method – Analytic Hierarchy Process (AHP) method

When determining the most appropriate method of selecting qualified employees for the requirements of Industry 4.0, we decided to use the AHP method. The AHP method is one of the most objective and effective methods of multicriteria decision-making. AHP as a flexible model for decision-making clarifies the problems that have several possible solutions. This method of multicriteria analysis is realized by an expert and by mathematical method, which divides the main problem into smaller and more detailed elements (Roháčová & Marková, 2009).

As a result, it is a managerial decision with several criteria, each of them may have a different weight, the AHP method is suitable in determining the most suitable method of qualified employee selection methods, considering the requirements of Industry 4.0.

As part of the work was used software Expert Choice 11.5. This software is Expert Choice, Inc.'s decision-making software based on multi-criteria decision making. It implements a process of analytical hierarchy based on criteria and also priorities for selection. The program uses a unique method to match the compared criteria at setting priorities. It combines the tools of teamwork and proven mathematical techniques and enables a complex structure of the problem, measuring the importance of competitive goals and alternatives, merging information, expertise, and opinions (Hrablik Chovanová & Sakál, 2012).

In the beginning, it was necessary to determine the main goal of research, which was to apply multicriterial decision-making method - the Analytic Hierarchy Process method to choose appropriate method of recruitment of qualified employees for newly created positions that arose during the implementation of Industry 4.0 in industrial enterprises.

Next step was to set up decision criteria. The criteria used in multi-criteria decision-making should be able to distinguish alternatives and allow for comparison. They should be complete, operational, relevant, encompassing all objectives, and their number should be limited (Baker et al., 2001). Based on analysis of current scientific research publications decision criteria are newly established crucial job requirements: (a) critical thinking needed for rational and objective analysis and evaluation related to work performance, (b) ability to interact with new modern interfaces, needed for continuous improvement and for flexible adaptation to changing technologies, (c) emotional recognition and management to strengthen relationships in working

teams, and ensure fast and especially effective communication across the entire work environment, (d) knowledge of English language required for the work performance because currently, English is the primary language of technological progress, and (e) extensive expertise in several technical areas.

Based on analysis of scientific research publications for the needs of our research AHP method´s alternatives are the most used and most common recruitment methods: professional competences test, personal interview, assessment centre, professional skills test, and personal questionnaire. All the elements of the hierarchy such as goal of research, all evaluation criteria, and individual alternatives were entered in the Expert Choice program (Fig.1).

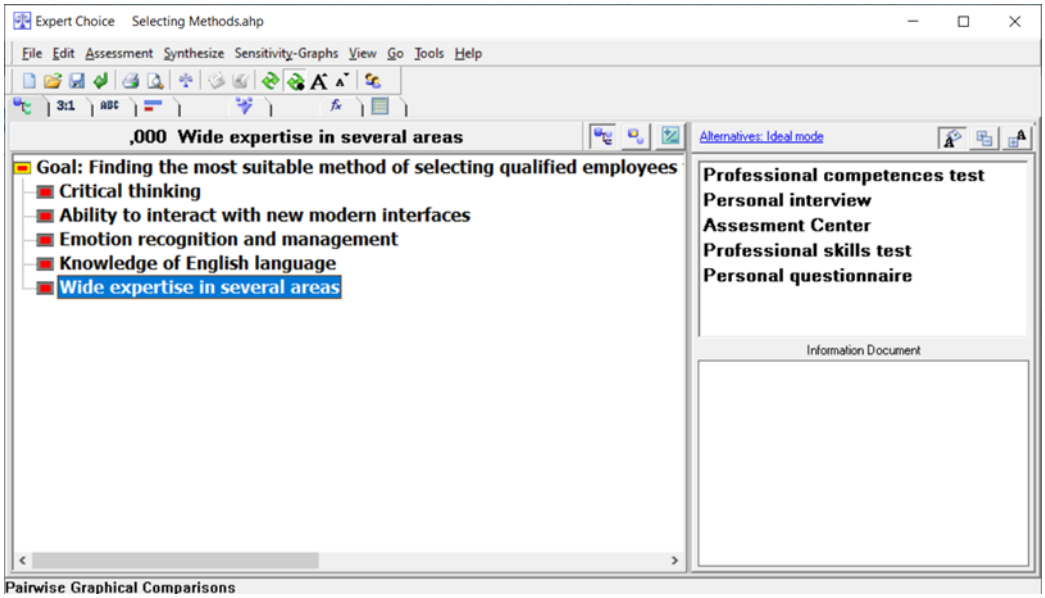

Fig. 1 – Expert Choice user interface with all elements entered. Source: own research

After determining the individual weight of each criterion, which were compared between each other (Fig.2), the importance of values of individual criteria were entered on the basis of the best practices in HR Management according to Industry 4.0 (Shamim et al., 2016; Rana & Sharma, 2019; Dhanpat et al., 2020; Piwowar-Sulej, 2020).

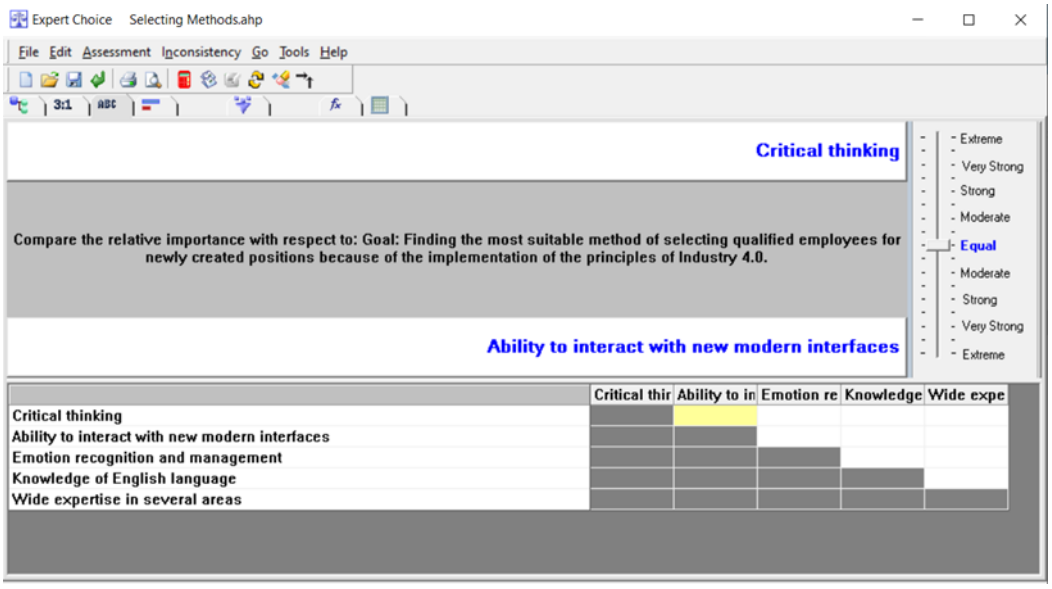

Fig. 2 – Pairwise comparison in Expert Choice. Source: own research

After performing a criterion pairing software ranked these criteria by importance and determined the order. The weight determination of individual criteria has a great impact on the final order of the solution. (Hrablik Chovanová & Sakál, 2012). Subsequently, the alternatives were compared against all criteria. The embedded value software evaluated and sorted all alternatives by the importance.

4 RESULTS

The following part of the paper contains the results of the analyses, which were performed using multicriterial method - Analytic Hierarchy Process method as it was implemented in the software package Expert Choice.

Expert estimation based on the best practices in HR Management according to Industry 4.0 determined the criteria and variants of decision-making, their comparison and compilation of the order of importance. The most important criterion in the initial pairwise comparison (Fig. 3) turned out to be critical thinking, followed by the ability to interact with new modern interfaces, knowledge of English language, wide expertise in several areas and last emotion recognition and management.

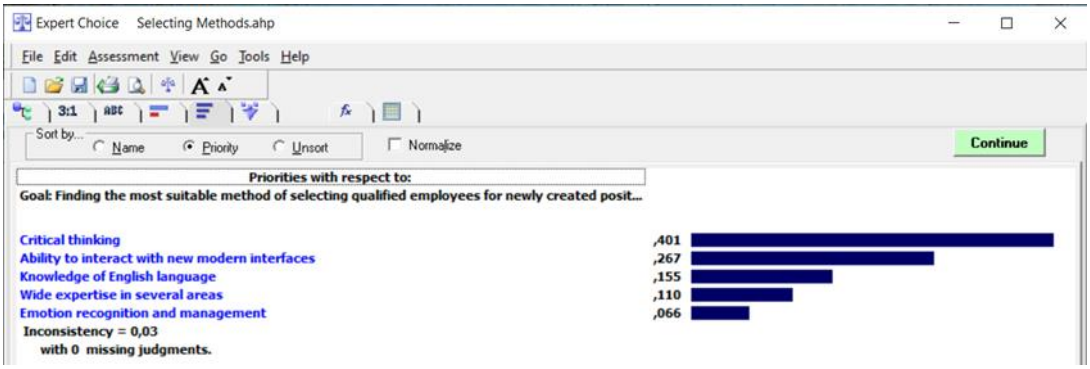

Fig. 3 – Expert Choice user interface with ordered criteria. Source: own research

The AHP method established the most appropriate method for selecting qualified employees of the Assessment Centre (Fig. 4) which is the most comprehensive, has the most notice period and has long been considered the most reliable. In this case, the change in employee selection requirements did not affect the effectiveness of the recruitment method.

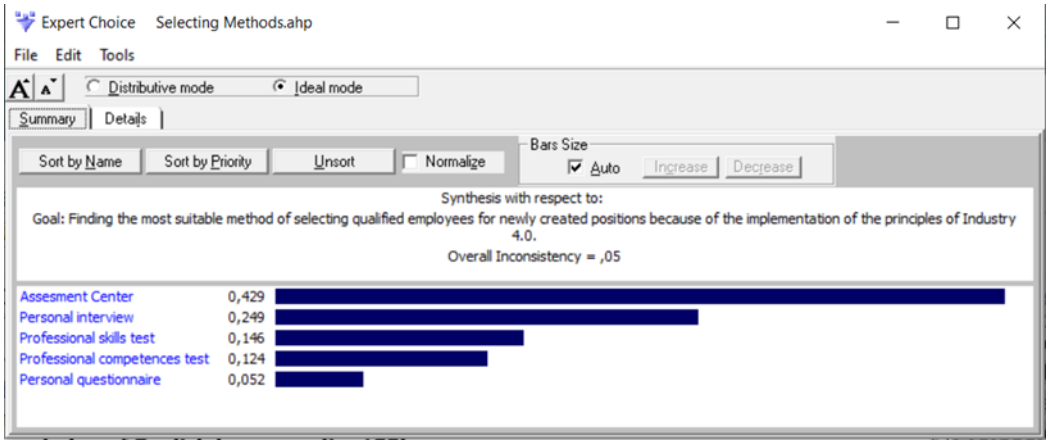

Fig. 4 – Expert Choice user interface with results. Source: own research

Managerial decision-making processed by the Expert Choice software supported the results from the past and confirmed the dominance of the recruitment method on the labour market.

Even if new positions are created and demands on employees are changing, the most preferred method - the Assessment Centre - is the most suitable and most comprehensive method of selecting qualified employees. It can cover psychological, behavioural, knowledge, professional and language requirements for the performance of work, even though it has different levels of success in each individual requirement.

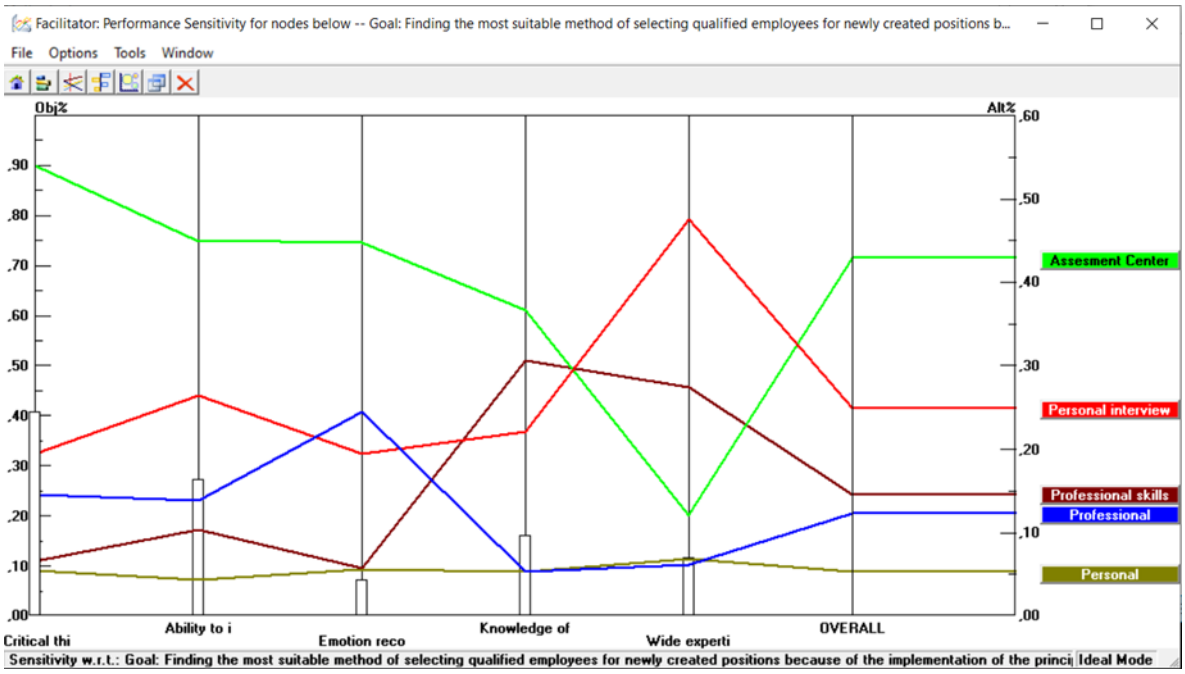

Fig. 5 – Expert Choice user interface with Performance sensitivity diagram. Source: own research

On Figure 5 is possible to see how the results of our research developed. The most general, most widely used Assessment Centre method was in almost every aspect an obvious winner in a pairwise comparison with any other recruitment method. The only example that manifests itself as its significant weakness is the criterion of wide expertise in several areas, where it has been clearly shown that the personal interview can better cover and reveal real knowledge of candidates from various professional fields. The Assessment centre in this regard is too general recruitment method and it is not possible to cover such a wide range of technical knowledge.

5 DISCUSSION

Human resource management plays a key role in the development of any business. The selection of an employee is not accidental but depends on various criteria, such as the skills required, the employee's commitment, etc. Therefore, multi-criteria decision-making is a suitable choice in the strategy of hiring suitable employees (Varmazyar & Nouri, 2014). Several authors have used the AHP method in recruitment in the past, but usually compared the weight and scope of different knowledge, experience, and abilities of several candidates, assuming the performance of a certain job position with predefined requirements (Hsiao et al., 2011; Ablhamid et al., 2013; Gustilo & Escolar-Jimenez, 2019; Güngör et al., 2009). Although our research was not the same as other existing and available research, they did agree in principle. In our case, we compared weight and scope of different methods of recruitment and their ability to assess the appropriate key competencies of employees in emerging positions within the implementation of Industry 4.0.

Based on theoretical research, expert judgment from scientific research and Expert Choice usage, the AHP Method has provided us with relevant results that give us a suitable basis for

further scientific analysis and research. The following scientific research will have to undoubtedly use also other new analytical and evaluation methods to set up trends in HR in terms of Industry 4.0. Based on results of this paper as well as the following researches we will hopefully be able to study and analyse emerging positions caused by the Fourth Industrial Revolution with focus on other key characteristics of qualified employees, propose improvements to the selection process to recruit, select and hire qualified employees with the greatest added value for the company and at the same time take into account the cost burden of the selection process of qualified employees for newly created positions that appear on the labour market due to Industry 4.0.

6 CONCLUSION

Nowadays if a company wants to continue in the market and gain a stable and competitive position, it is forced to keep up with constantly evolving technologies that affect the day-to-day operation. Provision of qualified workers who form the so-called the driving force of any company, is currently the most efficient in recent times. Constantly changes the filter to a new look at the key characteristics of employees, their analysis and redefining, which often creates more questions than answers. Attracting, selecting, and retaining qualified employees is the latest priority for every HR department. The aim of this paper was to determine the appropriate method of selecting employees in industrial enterprises according to requirements of Industry 4.0. To determine the most suitable and at the same time the most complex method of selecting qualified employees in industrial companies, we came to the conclusion that due to the multicriteria nature of the problem it is possible to use the AHP method in this field. The main goal of research was to apply multicriterial decision-making method - the Analytic Hierarchy Process method to choose appropriate method of recruitment of qualified employees for newly created positions that arose during the implementation of Industry 4.0 in industrial enterprises. The empirical results of this study found that the criteria and variants of decision-making, their comparison and the compilation of importance advice were determined at the same time. In our case, the AHP method determines the most appropriate method for selecting qualified employees of the Assessment Centre, which is the most comprehensive, has the longest notice period and allows the inclusion of a wide range of factors affecting the performance of work.

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EARLY PREDICTION OF STUDENT PERFORMANCE IN MASSIVE OPEN ONLINE COURSES AT DIFFERENT STAGES OF COURSE PROGRESS

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Abstract

Student success is paramount at all levels of education, especially for universities. Improving the success and quality of enrolled students is one of the most important concerns. It is important to monitor the early symptoms of at-risk students and take preventive measures earlier to identify the cause of student dropout rate. In this research, we will use data mining techniques to identify the factors that influence student success. We use the Open University Learning Analytics Dataset (OULAD) education dataset code module FFF and code presentation 2014J with 2364 students. We used grid search along with ANOVA ranked feature combinations in a pipeline to build our model. In this context, we will use Logistic Regression and Decision Tree for classification models. This research focuses on evaluating how predictions change over time after each test and how early we can obtain good predictive power. We built the model immediately after each exam in the course. The results showed that we can get good results very early in the course, which gives much more room for timely intervention.

Keywords: *machine learning, decision tree, student performance, OULAD dataset*

1 INTRODUCTION

Many areas of life are now dominated by digitalization, including education. The primary goal of these digital systems is to help businesses and institutions, and digital systems are producing more data than ever before (Guo et al., 2014). This data is not only used for business support in the context of transaction data but also increasingly used for decision making (Lei et al., 2016). By using data mining and machine learning, better decisions can be made in less time and proactively. To get a better prediction of student performance, an accurate predictive model is needed. There are a variety of insights that can be of interest to learners and instructors, such as providing student profiles, adopting course modules, etc. It makes most sense to find students who have a very high probability of failing an assessment and then help them with tutoring, but in time, before they fail the course. Of course, not all students have the same abilities, and some of them choose the learning path wrongly, and to avoid that, Learning Analytics intervenes by helping to create the learning path for each student based on their past performance and preferences. It can also help learners and teachers to intervene in time to support students or improve or adjust learning programs.

In Section 2, we will show some related work that has analysed the prediction of student performance using machine learning. In Section 3, we will describe the materials and methods used to achieve our goal. The results and discussion are presented in Section 4, while the ethical aspect is commented. Conclusion and future work can be found in Section 5.

2 LITERATURE REVIEW

Student performance refers to how well short- and long-term educational goals are met (Abu Zohair, 2019). To achieve these goals, there are many challenges and influences. It depends on how motivated the student is, how much effort they put in, how good the lecturer is, how good

the environment is for each student, how social (Ukut & Krairit, 2019) and all these influences have different effects before or during the exam (Starecek et al., 2017).

Most studies predict student performance after completion of the course, and these results are very useful in seeing what causes students to fail the course, but there are not as many studies on how to help students from failing or dropping out. Nowadays, virtual learning platforms generate enormous amounts of data at the very beginning of the course in terms of student interaction, clickstreams, courses, etc. By using this data right at the beginning of the course, a good predictive model can be developed to predict student performance early and give more room to help them proactively.

There is a study on predicting student outcomes in a course (Umer et al., 2019). For performance prediction Random Forest, Naïve Bayes, Logistic regression, Linear Discriminating analysis, and ensemble classifier which used weighted majority voting of all other listed classifiers. Four types of datasets were used: instructions partially online, course Introductory mathematics (C1), instructions fully online, course Introductory mathematics (C2), instructions internally on campus, course Software development (C3) and, fully online, course Introduction to finance (C4).

They saw that there is a big difference in the prediction of C1 and C2 record type. C2 has much higher predictive power than C1 in the early stages, but this is intuitive because C2 is fully online and provides much more information about student behaviour than C1. C3 was partially online but had five assessments during the course, while C4 was fully online but had no assessments. In these scenarios, C3 performed well in the early stages (not as well as C2, but much better than C1), while C4 did not. This led them to conclude that both the LMS and assessment results are very important in predicting student performance. There should be at least 3 assessments to get a good prediction, and more LMS data does not directly improve the prediction accuracy, but since it was only used at one institution, it cannot be generalized.

Another study used OULAD and prove that submitting the first assessment is a very good predictor of student performance (Wolff et al., 2014). This fact was used to split the data for the Markov chains and found that students who turned in the first assessment and had at least minimal contact with VLE did not withdraw from the course, and even if they had no contact with VLE, they still had a very low probability of withdrawal (Kuzilek et al., 2018).

Not only is classification used for prediction, but also regression. Prediction for student assessment using regression and prediction of final results using classification was performed for data from Massive Open Online Courses (MOOC) (Hassan et al., 2019). They predicted the student assessment scores and classification for the final results. They conclude that lower preliminary grades are a very significant factor for dropout, while engagement with the digital material is a very important factor determining overall student success.

All the studies discussed address predicting student success or what characteristics affect student success, and even predicting dropout at different percentages of course length, but none use exams as time points to model the data. This study with the proposed solution could help establish a proactive intervention system that could track and improve overall student performance.

3 METHODOLOGY

Many studies in the literature have used data mining techniques to predict students' performance (Injadat et al., 2020; Hassan et al., 2019; Helal et al., 2018). These studies have used individual classifiers such as Decision Tree (Myles et al., 2004), Support Vector Machine (SVM) (Noble, 2006), Artificial Neural Network (ANN) (Wang, 2003), Naive Bayes (Rish, 2001), and Random

Forest (Belgiu & Dragut, 2016). For this study, we will use Open University Learning Analytics Dataset (OULAD) (Kuzilek et al., 2017).

The aim of this paper is to predict student performance at different stages of the course. Predictions will be made after each exam, where we will see what predictive power, we have through the course timeline. The OULAD data is first pre-processed. Then feature extraction is performed to prepare the input for machine learning algorithms that classify student performance into one of two classes: failing or passing. Logistic regression and decision tree are used and compared based on the area under the ROC curve (ROC AUC). ANOVA is used for feature ranking, and k-fold cross validation of the different models is repeated with all features.

3.1 Data

The dataset for this study was provided by the research group Learning Analytics at Knowledge Media, The Open University. The dataset is publicly available and consists of tables containing information on student demographics, modules taken, module commencement (module presentations) and information on student academic success in the form of marks for assignments and examinations, and student interactions with the university's Virtual Learning Environment (VLE). OULAD consists of student data from 2013 and 2014, which was compared to 2015 data to see if there were any differences in the data. The conclusion was that there was no significant difference between OULAD and 2015 (test) data. OULAD has student-centred data where there are multiple data categories spread across multiple tables and linked to reference keys. The data categories are demographics, enrolment, assessments, and Virtual Learning Environment (VLE) interactions. The data includes 7 courses, 22 module presentations with 32,593 students (Kuzilek et al., 2017).

We chose module code FFF and presentation code 2014J for our modelling. There are 2,365 students in this module presentation. The OULAD data is divided into seven tables that are linked together with reference keys. The largest data is the data relating to student interaction with VLE. Student interaction with VLE is stored in the studentVle and vle tables (Kuzilek et al., 2017). After loading the data, we merge these two tables and filter data that does not relate to module code FFF and presentation code 2014J. We pivoted the student VLE interactions to get the sum of clicks for each activity type for each assessment date. We then merged studentAssesment and the assessment table (Kuzilek et al., 2017) and filtered the data not related to module code FFF and presentation code 2014J. We multiplied the weighting by the score, grouped by student and summed the values up to each assessment date. The assessment date is information about the final submission date of the assessment, calculated as the number of days since the start of the module presentation. For the selected course and presentation dates, we have 24, 52, 94, 136, 199 and 241 for the different assessment dates and the module presentation length is 269. A strong trend evident from the analysis of the VLE click patterns is that students often click more immediately before submitting an assessment. This can be clearly seen in Fig. 1 where the peaks of activity coincide with the period immediately prior to submitting an assessment. Therefore, when using VLE data, predictions are most useful when made during the periods between assessments.

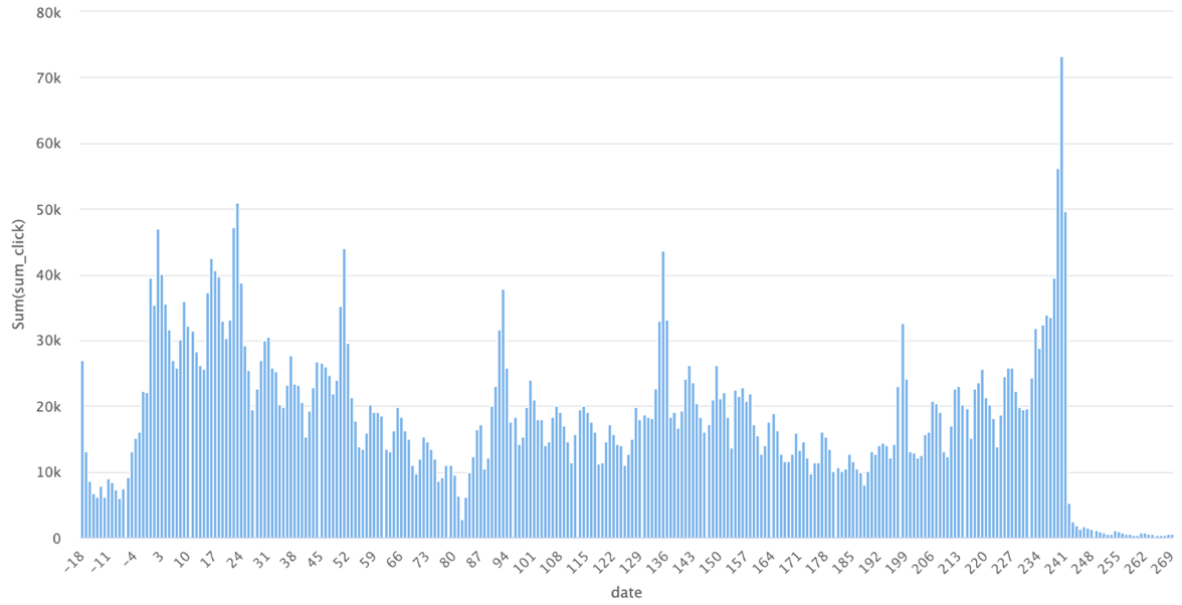

Fig. 1 – VLE total clicks per date. Source: own research

Having dealt with the VLE and assessment data, we filtered and merge all the other tables to have all the available features in one file, filtered for the chosen course and presentation. For the categorical features we have done the encoding. For the ordinal feature, we performed a label encoding where we replace the category name with a number corresponding to the rank. For ordinal encoding, it is important to maintain the order of the class so that no valuable information is lost, while for nominal features we should be careful not to create ordered features if we simply replace the classes with numbers, as this would provide misleading information to the algorithm, which could lead to a worse model. To encode nominal features, we used one-hot encoding. This involves removing the integer encoded variable and adding a new binary variable for each unique integer value in the variable. For binary features, we change the feature name to one of the two categories and set it to true if it was the same category as the feature name, and to 0 if it was not.

For the output variable, we mapped the final results with the four categories withdrawn, fail, pass, distinction to the binary variable fail where we mapped withdrawn and fail as 1 and pass and distinction to 0. As can be seen in Fig. 2, the distribution of students who did not pass and students who passed is balanced: 52.77% did not pass and 47.23% passed.

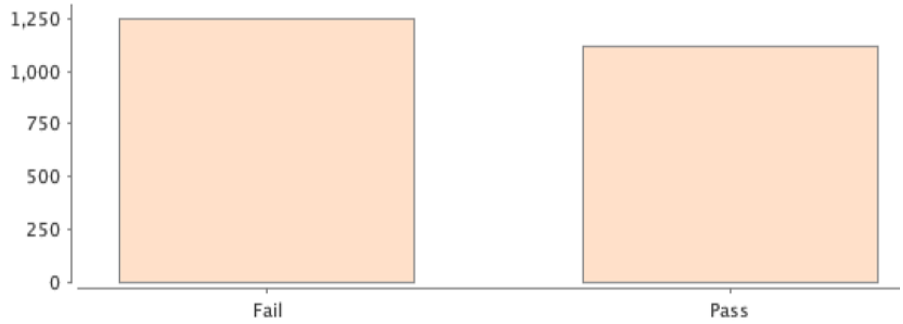

Fig. 2 – Student's course mapped (withdrawn, fail to fail; distinction, pass to pass) outcome distribution. Source: own research

The original distribution is shown in Fig. 3, where we can see that pass and withdrawn have almost the same ratio (36.32% and 36.15%), while there is an imbalance in fail and distinction

(16.62% and 10.91%), but when transformed into a binary variable, it is a balanced data set. We chose this mapping because the machine learning algorithms work better for binary classification (Sánchez-Maroño et al., 2010).

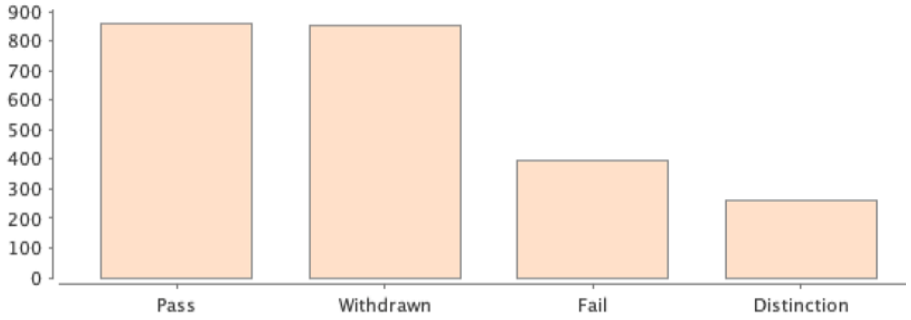

Fig. 3 – Student's original course outcome distribution. Source: own research

3.2 Methods

After data is prepared the modelling is the next thing to do. All techniques and methods for modelling in this study were performed in Python, version 3.9.1, using the following libraries: sklearn version 0.24.2, numpy version 1.20.1, pandas 1.2.1, and matplotlib version 3.3.3. PyCharm professional version 2020.3.4 is used to write the code, while Jupyter notebook is used for code mobility with the same Python version and packages defined previously (Project Jupyter, n.d.). RapidMiner version 9.9 was used, and everything is programmed on MacBook Pro with 2,4 GHz 8-Core Intel Core i9 processor, 32 GB 2667 MHz DDR4 and macOS BigSur version 11.4.

On prepared data, we output the Grid Search with features and hyperparameters in grid search and repeated stratified K-fold with 10 folds and 3 repetitions for cross validation. In grid search, care must be taken to train the model in a reasonable time, as there may be too many combinations to check.

For feature selection in Grid Search, we used the range from 1 to the total number of features in the dataset. For ranking the features, we used ANOVA scores (Gayatri et al., 2012). The hyperparameter grid is presented for each model as each model has different hyperparameters, as well as the final hyperparameters along with the number of best features selected based on ANOVA scores. ANOVA is an acronym for analysis of variance and is a parametric statistical hypothesis test for determining whether or not the means of two or more samples of data are from the same distribution (Gayatri et al., 2012).

For models, Logistic Regression and Decision Tree were used. Logistic regression is used for classification and uses the logistic sigmoid function to return a probability value. The most common use is for binary classification (e.g., email: spam or not spam). The algorithm is very similar to linear regression, but uses a more complex cost function, the sigmoid function.

Classification and Regression Trees or CART for short is a term introduced by Leo Breiman to refer to Decision Tree algorithms that can be used for classification or regression prediction problems. Classically, these algorithms are called decision trees, but on some platforms such as R they are referred to by the more modern term CART. The decision tree does not require the data to be scaled and it uses mutual information to obtain feature importance, which works for numeric and categorical data. Not only is it easy to work with enumerated things, but it also gives us results that are easy to interpret and code.

4 RESULTS & DISCUSSION

In this research, a set of problems for predicting student performance was defined. Data were processed, several models were developed and tested. The main findings are that we can predict student performance early in the course using data from OULAD. In addition, the choice of characteristics has a large impact on the reliability of a model generated from the data, regardless of what type of model is chosen.

The bar graphs showing the ANOVA scores for the data immediately after each of the assessments are shown in Fig. 4-9. We can see that the assessment scores are the strongest feature, while other features are important but not as much as the assessment scores, such as some of the VLE activity types and demographics. This is to be expected as the assessment score is strongly associated with the outcome. To pass the course at the Open University, you need to score at least 40 out of 100 to pass the course (Kuzilek et al., 2017).

In the Fig. 4, the ANOVA scores after the first assessment, we see that the weighted score is the highest at 1101.38, as expected, followed by subpages and homepages with scores of 633.44 and 612.80, respectively.

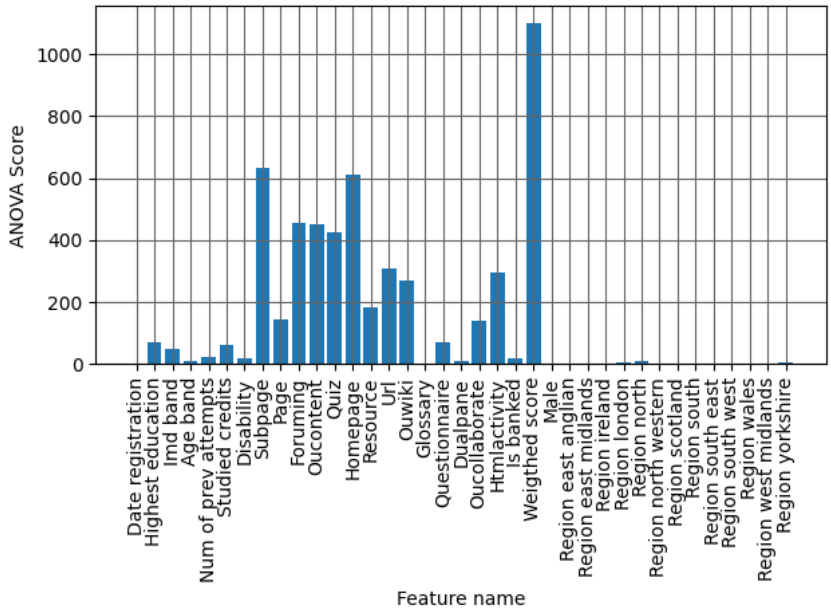

Fig. 4 – First assessment ANOVA scores. Source: own research

The ANOVA scores after the second assessment is shown in Fig. 5, and we can see that the weighted score is now much stronger than after the first assessment, but it is expected to become stronger after each assessment because we have more knowledge about the main part of the grade after each assessment. Here the weighted score is 2092.70, almost double. All the features related to assessments and VLE are higher because the time is further forward and there is more data, except for the information about students, which has not changed in the time after the first assessment to the second assessment.

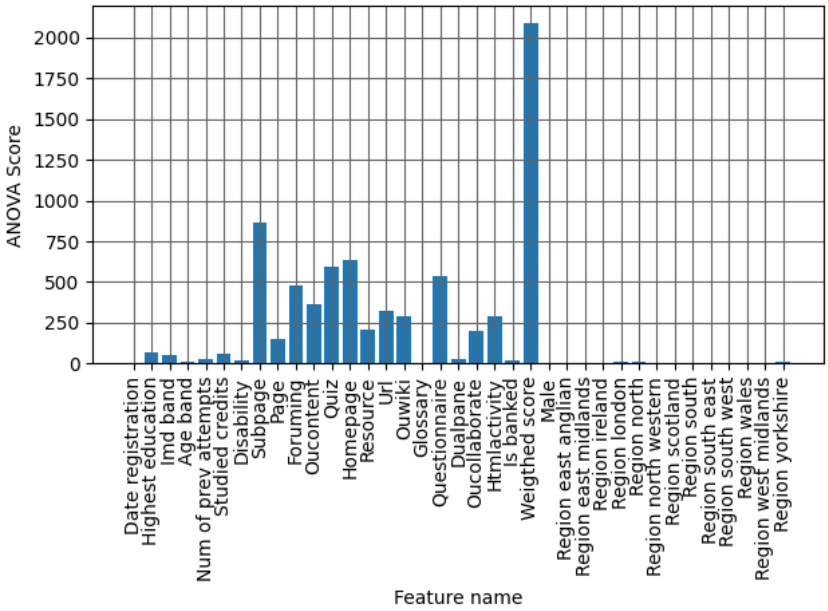

Fig. 5 – Second assessment ANOVA scores. Source: own research

In the third assessment ANOVA scores, which we can see in Fig. 6, the picture has changed in a similar way as after the first assessment and after the second assessment. The weighted score is now much stronger with a score of 4042.5, which is again almost double more than after the second assessment, while the other VLE activities now have a slightly better score, and the student information has the same ANOVA scores as before.

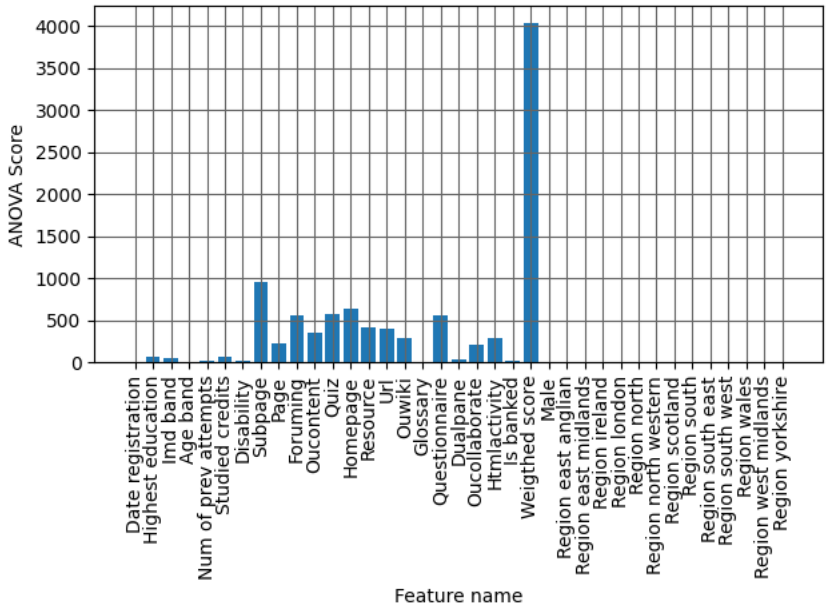

Fig. 6 – Third assessment ANOVA scores. Source: own research

After the fourth assessment ANOVA, which can be seen in Fig. 7, a change has occurred. As expected, the weighted score of 5837.31 is the highest and almost half better than after the third assessment, but now some of the VLE ANOVA values are higher and some lower than after the third assessment, but these are just indications of where there is more and where there is less activity.

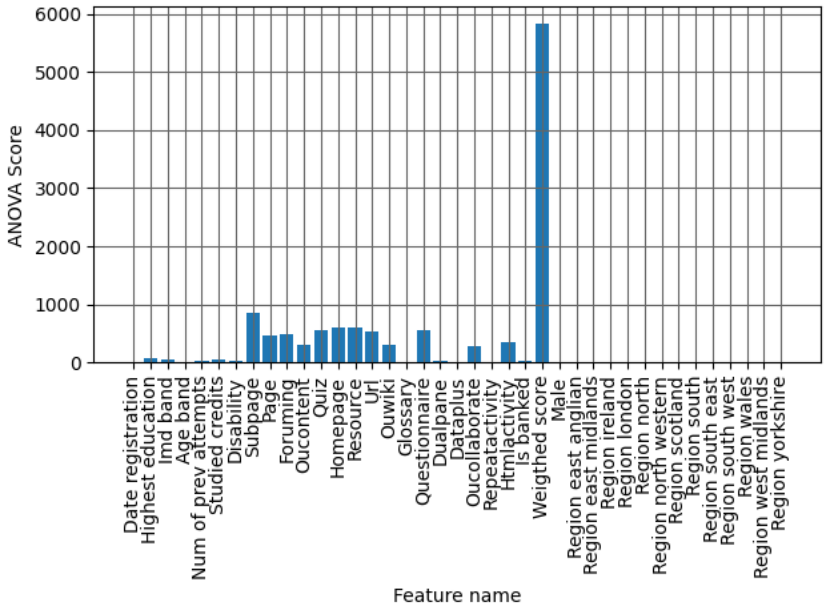

Fig. 7 – Fourth assessment ANOVA scores. Source: own research

After the fifth assessment ANOVA (Fig. 8) there are still big changes in the weighted score, which is now 8038.39, and some of VLE activities are higher and others lower, which only shows the dynamics.

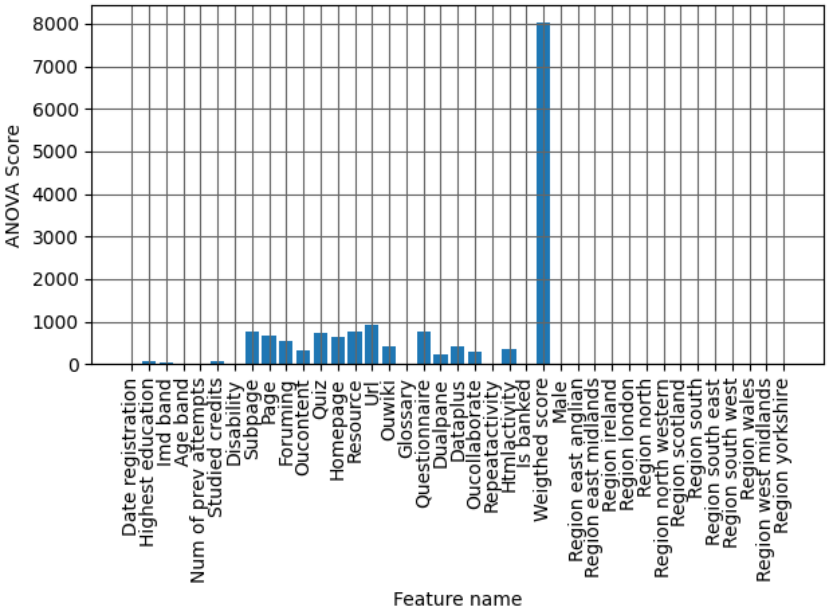

Fig. 8 – Fifth assessment ANOVA scores. Source: own research

After the last assessment or at the end of the course, the results of ANOVA are very similar to the results after the fifth assessment, as we can see in Fig. 9. In this case, the weighted score ANOVA has not changed, while the score for the VLE activities ANOVA is now higher, except homepage, suggesting more activities before the end of the course in the VLE system. As expected, there is no change in the ANOVA score for student information.

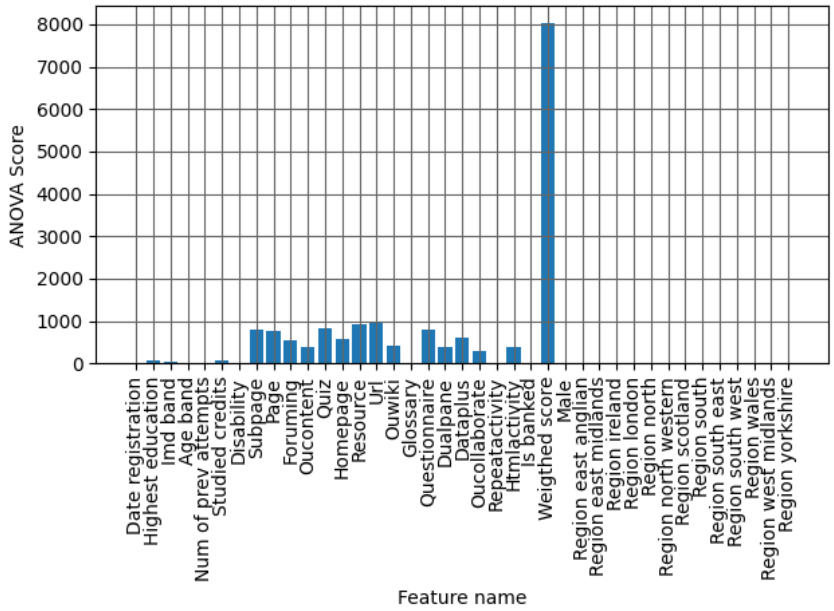

Fig. 9 – Sixth assessment ANOVA scores. Source: own research

To get a more detailed overview of the results from ANOVA, we present in Tab. 1 the ANOVA scores after each assessment for the VLE features and the weighted score. Here we can see the trends in detail and how the activities change over the course. If we look at the last two features, dataplus and oucollaborate, we will see that the score of ANOVA was 0 until the fourth assessment, which means that this VLE activity did not exist until the fourth assessment. As we can see, oucollaborate is not a feature that has a great impact on the final result. On the other hand, dataplus has no immediate influence, which indicates that dataplus was not very active at the beginning, but after the fifth and sixth assessment it becomes a strong feature with a high ANOVA value, as we can see in Tab. 1 in the last two columns.

Tab. 1 – ANOVA scores after each assessment for VLE features and weighted score. Source: own research

Feature name	ANOVA after 1. assessment	ANOVA after 2. assessment	ANOVA after 3. assessment	ANOVA after 4. assessment	ANOVA after 5. assessment	ANOVA after 6. assessment
Subpage	633,44	863,96	948,89	863,65	761,01	803,00
Page	143,67	150,75	231,87	456,14	685,08	764,07
Foruming	454,33	475,61	552,12	491,27	532,74	536,31
Oucontent	449,61	361,81	358,21	310,24	338,45	392,73
Quiz	423,02	594,56	572,69	564,79	718,67	813,11
Homepage	612,80	633,77	638,72	592,12	629,10	572,36
Resource	184,16	209,52	423,65	599,79	775,26	934,93
Url	306,23	323,67	402,29	540,49	934,18	956,70
Ouwiki	270,92	286,06	293,46	312,44	404,76	415,81
Glossary	2,45	3,71	10,32	14,16	16,32	19,55
Questionnaire	71,82	533,50	552,76	559,86	763,57	790,60
Dualpane	10,47	30,54	32,80	39,30	227,73	386,14
Oucollaborate	138,18	199,33	204,77	278,52	302,77	301,88
Htmlactivity	296,87	293,11	295,82	339,72	354,01	380,06
Weigthed score	1101,38	2092,70	4042,55	5837,31	8038,39	8038,39
Dataplus	0,00	0,00	0,00	6,42	414,79	617,83
Oucollaborate	0,00	0,00	0,00	1,12	1,12	1,12

After the analysis of the ANOVA scores, the next part follows with the hyperparameters, and the features ranked by ANOVA for the grid search and the results of the logistic regression and the decision tree.

The hyperparameters for Logistic regression are shown in Tab. 2 and these are only the values used for the grid search, while the other values are default values in the defined sklearn version 0.24.2. The penalty hyperparameter defines the norm used in penalty. The C value is inverse to the strength of the regularization and must be a positive floating-point number. Smaller values mean stronger regularization. Intercept scaling specifies what is used as the scaling value for a constant (also called bias or intercept) (Scikit-Learn, n.d. a). For the search of hyperparameters, the execution resulted in about 14 thousand combinations for each assessment dataset.

Tab. 2 – Grid search parameters and outputs for Logistic regression in sklearn. Source: own research

	Penalty	C	Intercept scaling	ANOVA Best K features
Grid values	L1, L2	0.1, 0.3, 0.6, 1.0	1, 2, 3	1, 2, … all
First exam	L1	0.3	1	28
Second exam	L1	0.1	2	30
Third exam	L1	0.1	1	34
Fourth exam	L1	0.1	1	37
Fifth exam	L1	0.3	3	37
Sixth exam	L1	0.3	3	37

The hyperparameters for decision tree are shown in Tab. 3 and these are only the values used for the grid search, while the other values are default values for the defined sklearn version 0.24.2. The function to measure the quality of a split. Supported criteria are Gini for Gini impurity and entropy for information gain. Splitter is the strategy used to select the split at each node. Supported strategies are best to choose the best split and random to choose the best random split. Min Samples Split is the minimum number of samples required to split an internal node. (Scikit-Learn, n.d. b) For hyperparameter search, we ended up with more than 50 thousand combinations to run for each assessment dataset.

Tab. 3 – Grid search parameters and outputs for Decision tree in sklearn. Source: own research

	Criterion	Splitter	Min samples split	ANOVA Best K features
Grid values	gini, entropy	best, random	2, 3, 4	1, 2, … all
First exam	gini	random	4	1
Second exam	gini	best	2	1
Third exam	gini	best	4	1
Fourth exam	gini	random	4	1
Fifth exam	gini	random	4	1
Sixth exam	gini	random	4	1

After grid search the best models were chosen and the prediction results of the stratified 10-fold cross-validation for the binary class fail true/false are shown in Tab. 4. From the results we can see that the deeper into the course the models are the more accurate, but this was to be expected, the more important it is that early in the course we can predict students who may fail. The decision tree shows less accurate models, but it only uses the score as a feature for prediction as it dominates all other features due to the very high correlation to the final score, whereas logistic regression uses more features and therefore performs slightly better. We can see that from the third test onwards the predictive power is very high. The standard deviation (STD) for stratified 10-fold with 3 repetition (30 tests in total) is stable.

Tab. 3 – Grid search parameters and outputs for Decision tree in sklearn. Source: own research

Method performance / Exam number	Logistic Regression		Decision tree	
	ROC AUC (STD)	Accuracy (STD)	ROC AUC (STD)	Accuracy (STD)
1. Exam	0.865 (0.019)	0.780 (0.024)	0.798 (0.028)	0.721 (0.029)
2. Exam	0.910 (0.016)	0.839 (0.017)	0.884 (0.019)	0.818 (0.022)
3. Exam	0.950 (0.011)	0.898 (0.017)	0.916 (0.018)	0.883 (0.016)
4. Exam	0.969 (0.009)	0.921 (0.016)	0.936 (0.013)	0.907 (0.015)
5. Exam	0.984 (0.006)	0.934 (0.012)	0.951 (0.014)	0.919 (0.016)
Final Exam	0.985 (0.005)	0.937 (0.014)	0.951 (0.014)	0.919 (0.016)

If we compare the results of this study with another study in which student performance was predicted at different percentages of course length (20%, 40%, 60%, 80%, and 100%) on the OULAD dataset (Adnan et al., 2021), we can draw a similar conclusion, when more and more course data were provided, the performance of the model improved. The improvement in student performance at the end of the course is not so useful to help the student, but the performance of the predictions is good in their case after 60% of the course and in our case after the 3. assessment and onwards which is the same as in the other study (Umer et al., 2019), but of course it depends how many assessments there are in the course.

4.1 Ethical Aspect of the Research

Since, in the research, OULAD dataset will be used which is already anonymized and prepare for public usage it will not result in personal information reveal. If any other university dataset will be used it is important that during publication no personal information will be published.

5 CONCLUSION

It would be helpful if the professor could predict student performance and identify students who need extra help in the course or in the field of study in general, or better yet, automate it to have a proactive system. In this work, the Logistic Regression and Decision tree algorithms are used on OULAD data to predict whether a student will fail or pass immediately after each assessment. We used ROC AUC as the assessment measure because it is a balanced metric for binary classification since it considers the true-positive rate and the false-positive rate. Considering this measure, logistic regression performs better than the decision tree. From the third exam, we get very accurate models where we can still help students in distress to overcome the problems and pass the course, which could be used for an automated early warning system where teachers can be notified and help the student or even automate it and the notifications to the student and try to motivate them early enough. We could combine a monitoring, alerting, and notification system where when it is detected, it first sends a notification with help to students with a high probability of failing, and if that doesn't help after the next test, it could alert the teacher where they intervene and try to help the student. This research confirmed the obvious, that the more time that passes in the course, the more accurate the models are, and that assessment results are the strongest feature. The more interesting part is that we can get very accurate models early in the course. The only downside is that we have 2365 students, which could be problematic for smaller institutions. Of course, since the decision tree only uses a single feature (the assessment scores), we could do this manually by checking what the student's score is after each exam, and we would most likely have a good prediction of which way the student will go, fail or pass. So why bother with all the modelling? Because why should we waste our time on something we don't need, it's better to use that time to help students pass the exam, and not only that, but some more complicated algorithms could give us an even better performance.

Future work should include more modules and presentations to check if this way of data preparation and modelling works for all Open University modules and presentations, and after that if it shows good results, it should be extended to other educational institutions. Future work should include more supervised machine learning algorithms to get even better performance earlier, the best case would be to get the good models immediately after the first exam.

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FOND MALÝCH PROJEKTOV

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HYDROGEOLOGIC MODELLING OF HAJDÚSZOBOSZLÓ AQUIFER SYSTEM TO DEMONSTRATE THE IMPORTANCE OF GEOLOGICAL HETEROGENEITY SPATIAL DISTRIBUTION OVER THE FLOW PATHS

Yetzabbel Flores, Zoltán Püspöki, Péter Szűcs

Abstract

The spatial distribution of geological heterogeneity has been of interest because of the proven effects on flow paths and contaminant transport phenomenon modelling, and the incorporation of stratigraphic and sedimentologic concepts for the construction of conceptual models improves the judgment to interpret the depositional system structures, creating a statement for a strong starting point to move into the numerical flow simulation. In this report will be evaluated the geological heterogeneity spatial distribution by assessing the effects of implementing a 3D facies rock model versus a 3D stratigraphic rock model for the steady-state modelling workflow of the Hajdúszoboszló aquifer system. Two geologic frameworks are developed from the same dataset using two different geological interpretation approaches. The aim is combining subjective geologic interpretation with hydrogeological data create an equivalent porous media. Model A represents the most common practice, where the hydrofacies are classified only for their hydrogeological properties, while the model B provide a deeper understanding of the geologic settings of the study area, as well as a better approximation for anisotropy parameters of hydraulic characteristics of the medium based on the facies characterization of each section of the model. At the end of the research, it is possible to visualize the contrast between models and evaluate the effects over the potential field and flow paths of the different geologic frameworks. It highlights the facies approach and why it is convenient for hydrogeologic modelling practice.

Keywords: *3D geology, facies analysis, anisotropy, geological heterogeneity*

1 INTRODUCTION

The optimum goal of hydrogeologic modelling is to solve a great number of hydrogeologic problems using fluid-flow and hydrogeologic simulation (Toth, 2009). But the problem is that to reach a successful simulation stage needs the conception of a realistic conceptual model because it plays a key role in the correct simplification of the problem.

Research into the mathematical behaviour of groundwater and contaminant transport at any scale requires the development of methods to describe more accurately and precisely the spatial variation of aquifer properties (Galloway & Sharp, 1998).

Our aim in this study is the definition of the geologic geometry by accurate interpretation of sedimentological parameters that control the hydrogeologic properties to give answer for the complex, three-dimensional, heterogeneous, and anisotropic real world. It will provide the spatial distribution of the heterogeneity within the aquifer and capturing the important structural aspects of the flow domain (Eaton, 2006b) as the hydraulic continuity of the layers (Toth, 2009).

It is known that loose fluvial sedimentary deposits, as the studied aquifer system, have an outstanding role in hydrogeology due to the general occurrence of coarse sediments complexes representing high-quality aquifers in terms of feasibility and production. Nevertheless, these are far from uniform coarse sediment bodies with ideal hydrogeological behaviour; usually,

they are embedded into fine sediment deposits forming aquitard layers which affect the aquifer performance flux in horizontal and vertical directions. As well, long-term variations in sedimentary processes determine the spatio-temporal distributions of the facies and cause the frequent and irregular occurrence of stratigraphic hiatuses of different orders that predetermine the aquifer hydrodynamic behaviour.

As a result, the hydrogeologic flow systems will require bigger spatial distribution scales that in consequence creates a high-resolution necessity in the description of the spatial distribution of geological heterogeneities of the system (Galloway & Sharp, 1998). Then, appears the presented problem, incorporating such kinds of geological features into hydrogeologic modelling using the facies analysis for deeper understanding of the aquifer system.

In the end, there are clear differences in modelling results between model A, based on hydrofacies obtained from the geological log of the boreholes, and model B, based on facies analysis interpretation from a set of logs (Geologic, SP, NGR, and R). They are shown and explained here by the established spatial effects of the lithological configuration over the groundwater flow phenomena and particle paths of Hajdúszoboszló aquifer.

2 THEORETICAL BACKGROUND

2.1 Geological heterogeneity and anisotropy

For hydrogeological modelling, the understanding of the spatial distribution of heterogeneities in the subsurface is essential for the aquifer characterization. Indeed, the starting reference of heterogeneity is made to geological variations, which includes grain-size, porosity, mineralogy, lithologic texture, rock mechanical properties, structure, and diagenetic processes (Eaton, 2006a) as a consequence of the way in which the layers have been shaped and reshaped over millions of years. These geological distinctions cause variations in hydraulic conductivity, storage, and porosity between layers; which are the determiner factors of flow and transport through the aquifer system (Buday et al., 2015; Toth, 2009; Cooley, 2004; Dutton et al., 2003; McCord et al., 1997).

In modelling practice, the flux is measured for every point of the macroscopic space within the continuum domain using average values of the variables over elementary volumes (Bear & Cheng, 2010) in what is assumed to be equivalent with *an ideal porous media* (Eaton, 2006b). Then, the potential field theory and the principle of mass conservation are applied as basic equations for analytical and numerical solutions.

Nevertheless, construct models based on the equivalent porous media would generate an underestimation of the real word complexity and obvious differences between model values and field values (Buday et al., 2015; Faragó et al., 2013). Consequently, the concept of hydrofacies (Poeter & Gaylord, 1990) is frequently applied in hydrogeology. One hydrofacie represents a homogeneous, anisotropic, and three-dimensional hydrogeologic unit (Atkinson et al., 2014; Maliva, 2016) used to convert the chaos in nature to a structured system. Hydrofacies are correlated with the lithofacies, but often it is not one for one (Atkinson et al., 2014). Their interrelationship is constrained by the scale of the considered problem and the heterogeneities (Anderson, 1989).

The heterogeneities causes that in space the hydraulic conductivity directions presents principal directions, where the flux has a higher value (Toth, 2009). For example, in sedimentary porous media, the sedimentation and overlaying pressure create favoured orientation of the particles where the flow channels are parallel to the bending plane producing differentiation in the flow path.

When a heterogeneous porous medium domain is under analysis, perhaps the principal directions will vary from point to point (Bear & Cheng, 2010), and the potential field will present perturbations (Toth, 2009). Then, anisotropy became a scale-dependent problem, related to the calculation of relative horizontal and vertical hydraulic conductivity harmonized with the hydrofacies concept and the simplification fact (Maliva, 2016), as well as highlighting the importance of known the sedimentary environment implicit by facies identification.

The grade of homogeneity of a porous media is determined by a comparison between the length scale of the phenomenon of interest and the length of the inhomogeneity within the porous media (Bear & Cheng, 2010; Heinz & Aigner, 2003). It means in larger scales models (regional), less variance of hydraulic conductivity for reason that less geological heterogeneities will have incidence, and the model will contain limited internal variability (Ross et al., 2005; Schulze-Makuch et al., 1999).

For example, an inhomogeneous material composed of alternating layers of different textures, say low permeability silt and high permeability sand; and where the thickness of the individual layers must be much smaller than lengths of interest, is equivalent in its overall behaviour to a homogeneous anisotropic porous medium (hydrofacie) in which the permeability parallel to the layers is larger than that perpendicular to them (Bear & Cheng, 2010).

In order to simplify the geological characterization and heterogeneities of the porous media, the anisotropy is considered to create an analogous homogeneous medium that simulates the real conditions of composing layers at the adequate scale of the representative macroscopic elementary volume. For example, in an intermedia scale model, choose between the representation of the hydrofacies on lithological level or on facies level may explain the drawdown differences between close wells (Buday et al., 2015).

The subjectivity of the numerical scale from the commonly used qualifiers of ‘local’, ‘intermediate’ and ‘regional’, terms which used to depend on the size of the area of interest was reviewed by J. Thot (1963, 2013) who established the effects of the water table undulations in a unit basinal environment, resulting on a hierarchically nested flow system, where every system has three identifiable segments: recharge, midline, and discharge (Fig. 1). The hierarchically nested flow system is termed *local flow* if its recharge and discharge areas are contiguous, *intermediate* if these areas are separated by one or more local systems but do not occupy the main divide or valley bottom, and *regional* if it links the basin’s principal divide and thalweg hydraulically. The coexistence of the three hierarchies is tied to the basinal depth and width (Toth, 2009).

Meanwhile, Galloway and Sharp (1998) describe five levels of heterogeneity scales, (1) *gigascopic heterogeneity* has regional aquifer scale impact, and it describes depositional systems and stratigraphic sequences around 1+Ma duration. (2) *Megascopic heterogeneity* has well-field scale importance, and it describes the external border and interrelation of permeable units. (3) *Macroscopic heterogeneity* is of critical importance to accurately predict and understand the flow pathway, it used to occur at the limit of spatial resolution and must be guided by predictive quantify facies analysis. It describes the next features: compartmentalization, permeability distribution, and stratification. (4) *Mesoscopic heterogeneity* is important to understand permeability anisotropy and its maximum values. It is a function of the stratification and occurs in bedding and lamina-scale variation. Finally, (5) *Microscopic heterogeneity* is usually studied at the laboratory level to understand the relationship between permeability, porosity, pore geometry, and sediment texture. It is described at individual grains and pore levels.

2.2 Facies analysis

Facies is a body of sedimentary rock with specified characteristics, which may include lithology (lithofacies), fossils (biofacies), and hydraulic properties (hydrofacies), and a really restricted. An idealized sequence of facies of a specific sedimentary environment can be represented as model. In other hand, sequence stratigraphy is based on unconformity-bounded sequences, which reflect the sedimentological response to sea level changes, subsidence, and sediment supply (Maliva, 2016).

This data can allow for more accurate interpolation and extrapolation than limited point data, and its use recommended for hydrogeologic modelling because they can be defined on a variety of scales depending upon the purpose of the study, the time available to make the measurements, and the abundance of descriptive features in the studied microscopic characteristics at the macroscopic strata.

The above numbered facts permit apply them in the next ways (Galloway & Sharp, 1998; Maliva, 2016): (1) Geologically, selection of appropriate analogues and realistic conditions for input parameters to flow simulations. (2) Deterministic prediction of trends in hydraulic conductivity from a limited number of point measurements, guiding interpolation of the punctual quantitative data. (3) Assessment of the validity of stochastically determined distributions of hydraulic conductivity. Finally, (4) guide wells placement and the interpretation of aquifer test data, and also the density of sampling.

Facies models use to reveal the structure of an aquifer system derived from the knowledge of the depositional environment of the strata and the likely orientation, scale, and connectivity of aquifer and confining strata. Also, the results of facies analyses can provide quantitative information on spatial correlation and can also be used as soft information or training images for geostatistical methods.

Facies and hydrofacies analyses are not a replacement for field data collection. Currently, facies and hydrofacies analyses should be approached as methods to maximize the value obtained from collected data. The limitation of the facies analysis concerning fluvial deposits became from the fragmentary preservation and variability of fluvial sediment. Facies models are less useful for delineating small-scale heterogeneity within facies because small-scale spatial trends are dependent on local site-specific conditions. Despite its limitations, facies modelling has been demonstrated to be an invaluable tool for the analysis of sedimentary deposits and ultimately aquifer characterization.

3 METHODOLOGY

3.1 Study area introduction

Hajdúszoboszló is a tourist town located about 21km and SE direction from Debrecen, Hajdú-Bihar county, in the eastern region of Hungary. The study area covers 3095 m of length and 2565 m of width, giving a total of 16,16 km^2 between the coordinates 828579N; 236951W (EOV, 1972) and 831701N; 234361E (EOV, 1972) (Fig. 1).

Geographically, Hungary is placed in the Pannonian Basin, surrounded by the Alps, the Carpathians, and the Dinarides. Physiographical, it is characterized by extensive lowlands called the Great Plain and the Little Plain, where the main hydrological system is constituted by the Balaton lake and the Danube river with its tributaries: Raba, Tisza, and Drava (Haas et al., 2002).

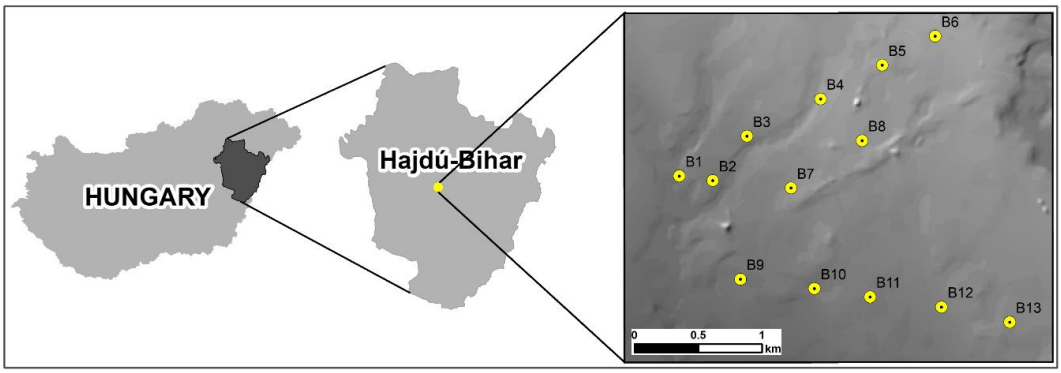

Fig. 1 – Location of the study area, and within it the boreholes which were used as source of information.

Source: own research

The geological features of Hungary are determined by its late Cenozoic evolution when large basins came into being. After, large sedimentary series from Late Miocene-Pliocene Pannonian Lake filled up the basins. And finally, they are covered by Quaternary deposits (Haas et al., 2002). The Pannonian Basin shows a complicated Late Cenozoic mosaic of heterogeneous terranes derived from the Tethyan realm. The pre-Neogene basement is divided by the ENE-WSW trending Mid Hungarian Lineament into two large units with different geologic histories: the Tisza Mega-unit and Alcapa Mega-unit (Haas et al., 2002).

In fact, the study area placed in the Trans-Tisza region, inside the inter-terrestrial Great Hungarian Plain where an alluvial succession of Quaternary fluvial deposits (Puspoki et al., 2016) originated from the uplifting of Alpine-Carpathians mountains, had been placed in Pliocene age (Cserkész-Nagy et al., 2010), and it was accompanied by the Tisza river migration. This stratigraphic sequence is considered as the "waterworks" aquifer system (Szűcs & Madarász, 2006) in the region. Furthermore, two different sedimentary facies are able to coexist into the Quaternary sediments, a lacustrine and a floodplain depositional environment. They lie over the pre-quaternary Pannonian sediments.

To the Hajdu – Bihar study area, the explained geological condition makes the hydrogeological environment complicated, that is supported by the fact that fluvial stratigraphic sequences of the braided rivers, as the Tisza river is; are built by non-uniform sequences of layers, cross-beddings, and gradual changing deposits (Comunian et al., 2011).

3.2 Modelling workflow

To construct the steady-state hydrogeologic simulation of the study area with the aim of disclose the effects of geological framework over the flow-paths and how the facies analysis contributes into the process, a workflow of three steps is followed. First, collection of the information, after construction of the two rock frameworks, and then apply the numerical modelling under the same hydrogeologic conditions for both 3D rock models.

The methodology used stars with data digitalization of the data of 13 well books (Fig. 1), form where are found the technical borehole description, geologic information, and geophysics data as gamma-ray log, self-potential log and electrical resistivity log. The geographic information is provided by the Institute of Geography and Geoinformatics of the University of Miskolc, and the climate records are downloaded from the Hungarian Meteorologic Records (Országos Meteorológiai Szolgálat).

In a second stage, the geologic interpretation take place using two approach: (1) lithostratigraphic interpretation and (2) facies analysis interpretation. With the geological models complete, the hydrofacies for each one had been delineated and characterized. The

horizontal hydraulic conductivity (k_h) of the screened layers of the wells is calculated applying the Darcy's Law formula (Formula 1) under Dupuit – Thiem conditions with the assumption of confined aquifer (Coldewey & Holting, 2018) layers where the radius of influence is defined by Sichardt's formula (Formula 2).

$$Q = 2\pi bk \frac{H - h_0}{\frac{lnR}{r_0}} \quad (1)$$

$$R = 5000 s_0 \sqrt{k} \quad (2)$$

Then, taking as reference the calculated hydraulic conductivity values (k_h), the other hydraulic properties are assigned from theoretical tables and bibliographic sources (Şen, 2015; Borden, 2006; Freeze & Cherry, 1979) to fulfil the essential information to reproduce the current flow conditions of the systems.

Regarding the hydraulic components of the models, the boundaries conditions are fixed as specific head (cell value = -1) boundaries (Fig. 2b) at north and south of the aquifer layers, based on the hydraulic gradient of the area showed by the starting head (h) distribution. It is calculated by interpolation of the piezometric level of the boreholes. Also, a set of production well are incorporating (Tab. 1) using the location and screen data of boreholes B3, B8, B9, and B12, as well as the average pumping rate recorder in the documentation as flow rate for modelling.

Tab. 1 – Technical data and potential head of the used boreholes. Source: own research

Id screen	Borehole	Initial head			Q	Screen	
		h	h_z	z	(m^3/d)	Top m. aBs	Bottom m. aBs
1	B3	-6.0	92.7	96.3	309.60	29.34	20.34
2	B3	-4.0	92.3	96.3	309.60	16.34	7.84
3	B8	-10.3	89.9	99.4	767.98	44.44	38.44
4	B8	-11.0	90.3	99.4	196.82	26.44	18.94
5	B9	-10.0	89.4	94.6	196.42	25.56	18.06
6	B9	-10.2	88.0	94.6	357.12	15.06	4.06
7	B9	-6.8	87.8	94.6	339.26	-2.44	-13.44
8	B12	-8.0	87.5	96.0	479.81	10.51	4.51
9	B12	-6.5	88.1	96.0	499.39	-0.99	-9.99

Groundwater Modelling System (GMS 10.1) was chosen as a graphic interface unit, which supports complex stratigraphy model construction (Aquaveo, 2013) by various interpolation methods. It also allows simulating the natural groundwater flow in steady stage conditions by USG-MODFLOW code (Panday et al., 2013) and using Voronoi unstructured grid configuration. Also, the finite difference method of the mod-PATH3DU (Pollock, 2016) tracking module, incorporated into GMS 10.1 as well, it had been used to model the water particle paths with intervals of 5 years (Fig. 4).

4 RESULTS

4.1 Geologic results

The rock framework to Model A (Fig. 2) is developed by interpretation of geological logs and making conservative assumptions of continuous lithological correlation on space; meanwhile, the Model B (Fig. 2) is constructed applying the facie correlation of geological and geophysical logs, starting from definition of the main facies' surfaces, and after adding the lithology into them to fit with the scale of the study.

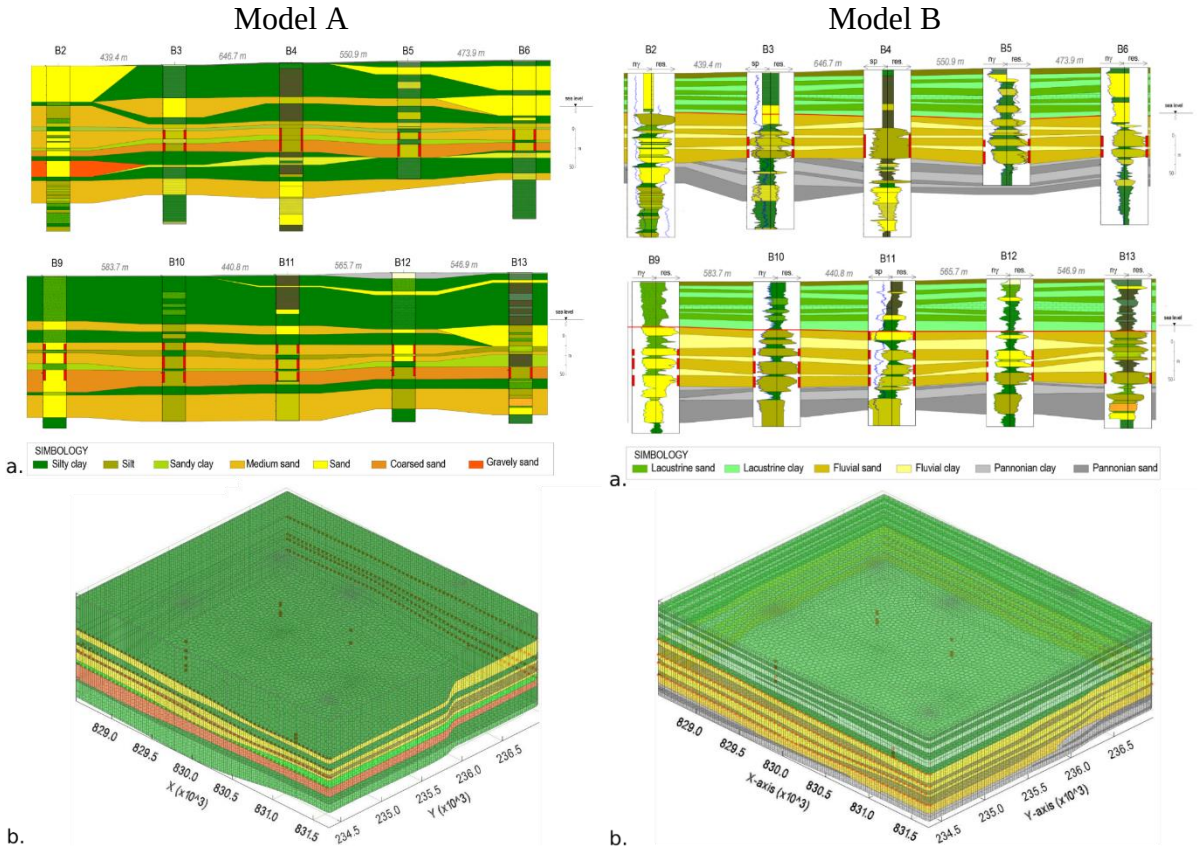

Fig. 2 – Conceptual Model A and Conceptual Model B. (a) Cross-section SW-NE using the related geological interpretation approach, and (b) the final 3D rock models with the same established boundary conditions, sink, and sources. Source: own research

In Model A are described ten hydrofacies defined from five cross geologic sections interpreted between boreholes, where the anisotropy value is assumed 10, and supported with diverse studies over Hungary. The lithologic layer over the aquifer system is described as a unique aquitard hydrofacie composed by silty sand, silty clay, and limestone. The aquifer system has intercalation of sand and coarse sand layers, with silty clay ones. Finally, at the bottom of the aquifer system are found silty clay sediments.

Meanwhile, in Model B are described 22 hydrofacies separated grouped in three facies: lacustrine, fluvial, and Pannonian Sediments as the bottom of the basin. The stratigraphic correlation within the facies was done from five cross geologic sections. Here, the anisotropy factor is assigned with reference in the sedimentary facies of the layer, and supported in the bibliography (Chen, 2000; Faragó et al., 2013; Lu et al., 2012). The lacustrine facie is the upper seal of the aquifer system, and it is composed by intercalation of silty sand and clay layers. The aquifer system comprises the fluvial facie, here is found intercalation of sand and clay layers. Finally, these two facies are located over the fine to medium grain sediments of Pannonian age which constitute the bottom of the basin and the seal of the aquifer system.

4.2 Hydrogeologic results

From the steady-state modelling process are described two clear results: (1) the potential head distribution (Fig. 3), and (2) the flow path of the water particles (Fig. 4).

First, to realize the different behaviour of the two models, the starting hydraulic head (Fig. 3a, 3d) is setting up from the registered data of the wellbooks using ordinary kriging interpolation.

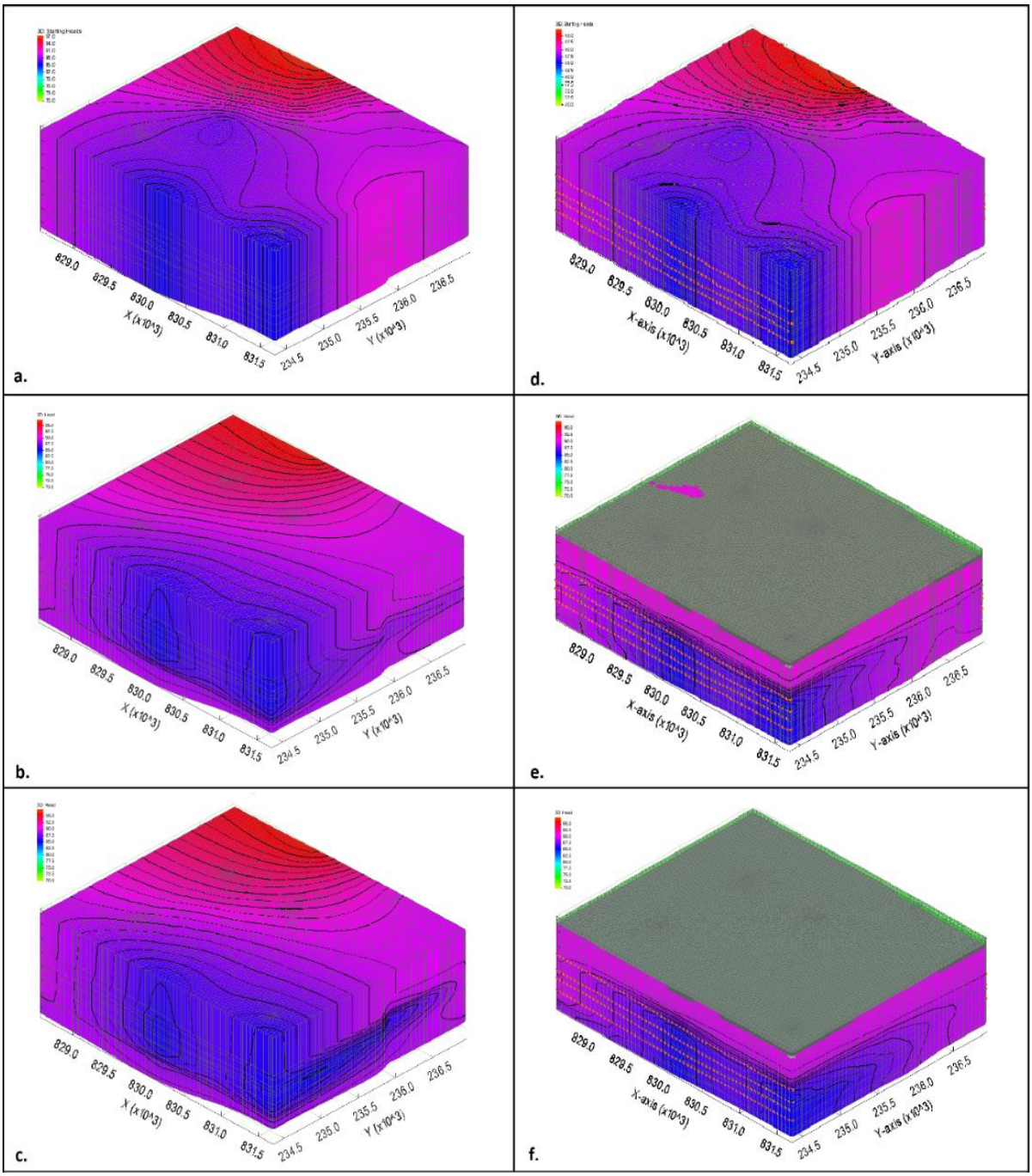

Fig. 3 – Potential head distribution for the Model A (left) and Model B (right) at different modelling stages. The initial potential head (a and d), steady-state simulation (b and e), and steady-state simulation with four production wells (c and d). Source: own research

It has a range between 97m and 85m above the Baltic Sea with a flow direction of NW-SE which coincidence with the aquifer's layers dip. Next, the head distribution is modelled for Model A (Fig. 3b) and Model B (Fig. 3e) using their respective conceptual model (Fig. 2). Finally, the simulation with incorporation of production wells (Tab. 1) is displayed (Fig. 3c, 3f), here are showed notorious differences in the dynamic performance of the aquifer section and its interaction with the surrounding layers even though the flow rates still the same for both models.

Concerning the flow paths, the particles backward path from the production wells into the system of Model A (Fig. 4) and Model B (Fig. 5) were modelling with use of 20 particles by screen in the same aquifer layer. Using particle tracking, the contribution zones of the wells have been schemed (Fig. 4 and 5, purple line), as well as the travel time.

5 DISCUSSION

At the end of the investigation is visible the impact that the geological framework has over all hydrogeological modelling process. It guides the interpretation, selection, and use of hydrogeological characteristic of the defined hydrofacies. Also, the geological framework is the geometrical definer of the hydrofacies, but its heterogeneity is outlined for the scale of the project.

In the study case, Hajdúszoboszló water supply aquifer system, the facies interpretation of Model B helped to understand the relation between aquifer layers and production wells under the premise that all the productive layer are part of a sedimentary sequence of fluvial deposits, fact that cannot be discretise from model A (Fig. 2).

Comparing the obtained results of the groundwater flow simulation into Model A and Model B it evident the higher fall down of the hydraulic head is observed in Model A than in Model B during the well production stage; which can be interpreted as aquifer overproduction. The difference between Model A (Fig. 4) and Model B (Fig. 5) is obvious in area extension of the budget zone, travel time of the particles, and the followed path by particles until them reaches the wells. The production budget zones and the head potential depression also are directly related with the geometrical configuration of the hydrofacies.

The obtained results support the fact of how important a correct resolution of the geological component is. It starts with a qualitative approach, and open the door to the necessity of combine the process with quantitative characterization of the data through incorporation of geostatistical procedures that allow figure out the level of uncertainty of the model.

6 CONCLUSION

It is evident that incorporate a deeply understanding of the geological features of an aquifer system will contribute to reinforce the results of the modelling process, because thought the present report shows that:

The geologic framework used to perform the groundwater flow modelling has an impact on the head distribution and aquifer performance under the dynamic influence as injection or extraction practices.

The use of geophysical logs to interpret the geological relation and define the stratigraphy will decrease the uncertainty of the rock model.

The stratigraphic facies correlation insertion in the hydrogeological modelling practices will contribute to a better understanding of aquifer's behaviours, as well as great interpretation of field test results.

The importance of integrate subjective geological interpretation with approach as geostatistical analysis that allow quantify the level of uncertainty of the models.

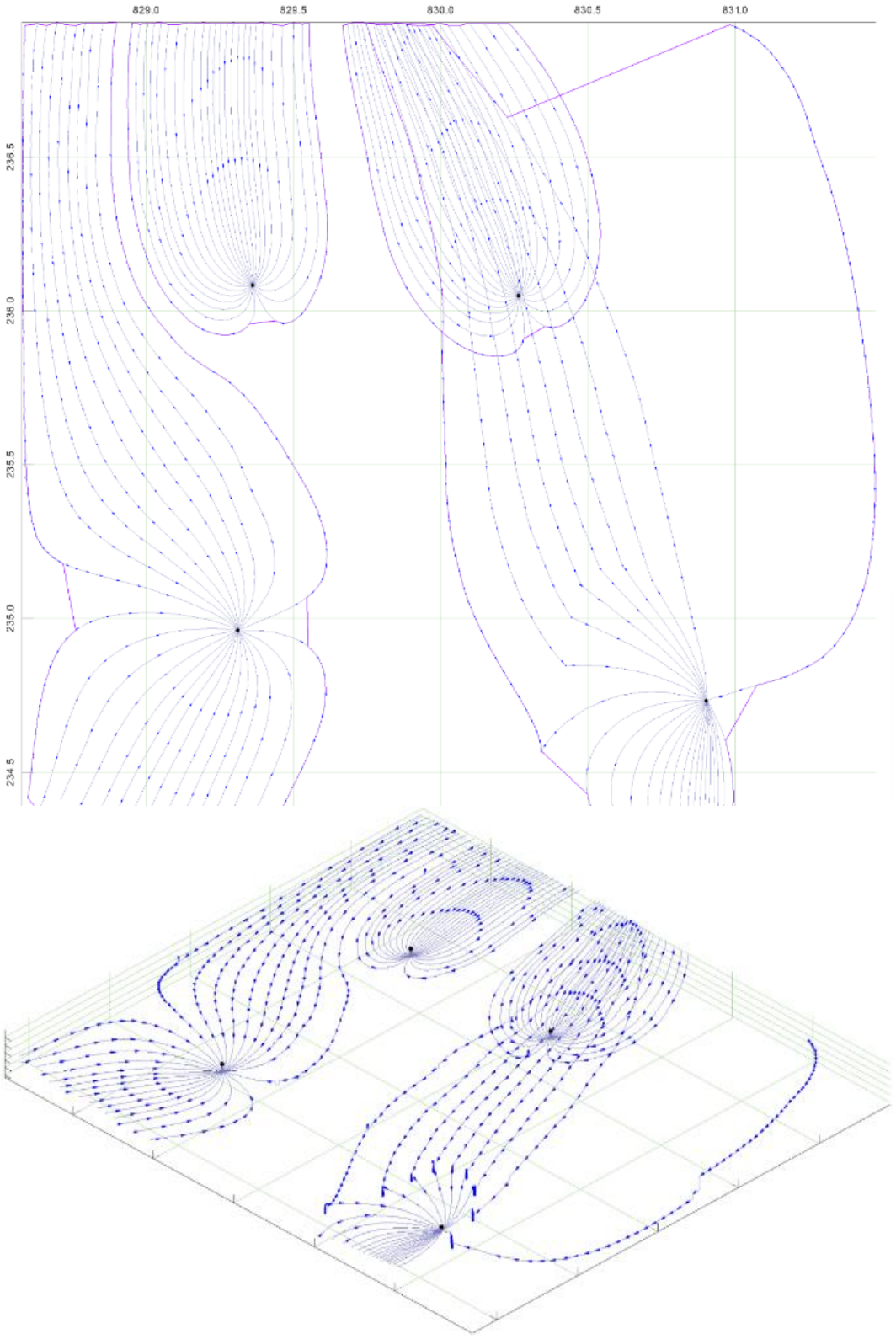

Fig. 4 – Particle's flow paths into Model A. The particles were located at the screened section specified in Table 1, and the blue arrows show the position of the particles every 5 years. Source: own research

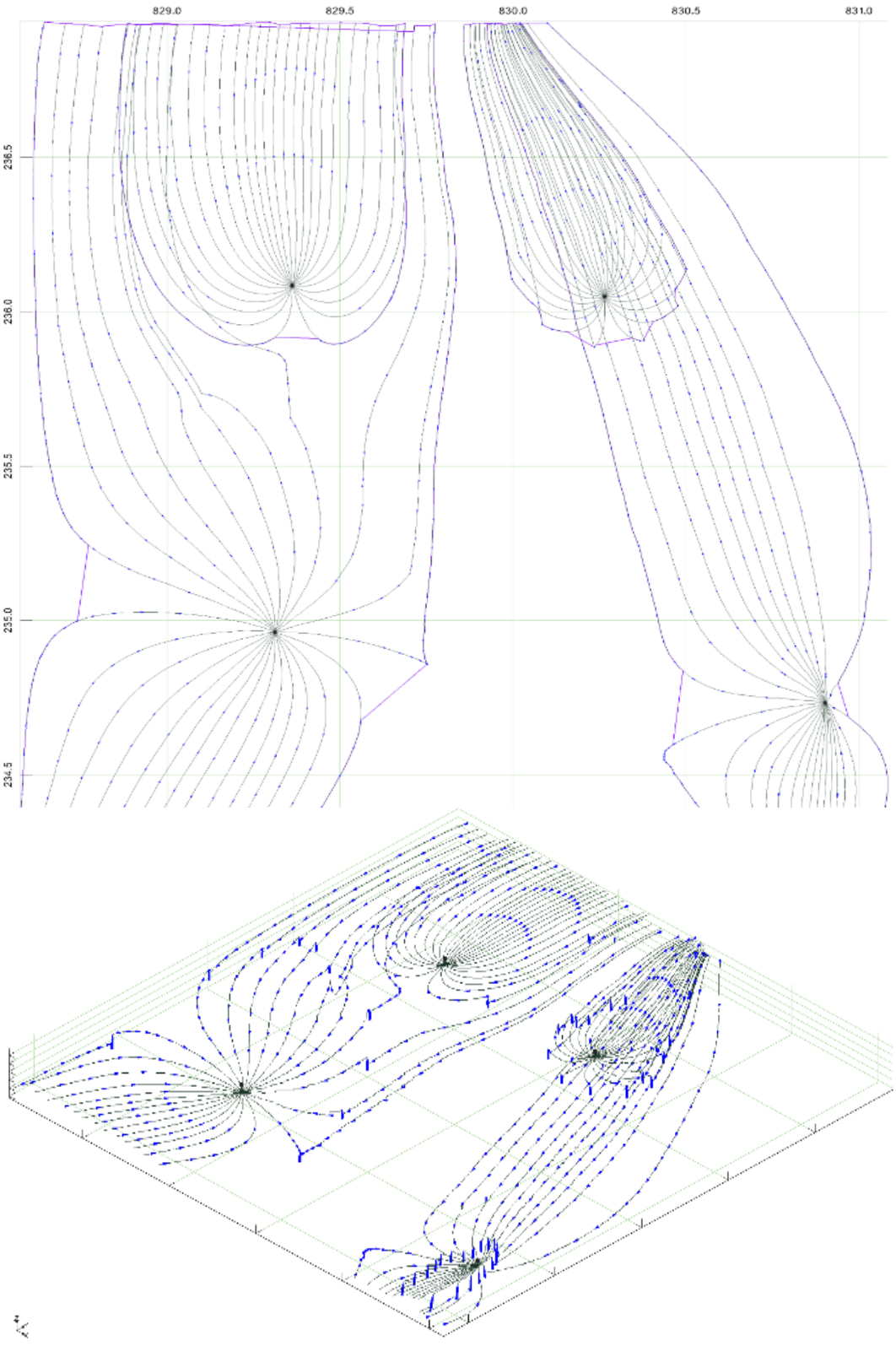

Fig. 5 – Particle's flow paths into Model A and Model B. The particles were located at the screened section specified in Table 1, and the blue arrows show the position of the particles every 5 years. Source: own research

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INFLUENCE OF GERMICIDAL UV RADIATION ON POLYMERS AND COMPOSITES

Peter Godovcin, Alica Pastierova

Abstract

The objective of this article is to report experimental results concerning the effect of accelerated UV-C ageing on the properties of samples polyamide and composite of polyphthalamide and glass fibre Four samples of each material have been studied after the exposition of UV-C radiation in a closed chamber. Degradation was monitored by changes in aesthetic and material properties. Aesthetic properties were monitored by colour change. The properties of the material were monitored by changing the hardness. Based on the observed changes, it can be argued that exposure to UV-C radiation on the studied samples will affect the aesthetic as well as material properties of the samples. On the tested samples can be observed a visible change in colouration. The decay of the existing chemical bonds, caused by UV-C radiation resulted in a new crosslinking of the polymers in the surface layer of the material, which was reflected in a slight increase in hardness.

Keywords: *Ultraviolet, germicidal, degradation, polymers*

1 INTRODUCTION

The global health-threatening crisis from the COVID-19 pandemic, caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), highlights the scientific and engineering potentials of applying ultraviolet (UV) disinfection technologies for biocontaminated air and surfaces as the major media for disease transmission. Nowadays, various environmental public settings worldwide, from hospitals and health care facilities to shopping malls and airports, are considering the implementation of UV disinfection devices for disinfection of frequently touched surfaces and circulating air streams. (Raeiszadeh & Adeli, 2020)

The risk of viral infection could be reduced through many control techniques, including heat sterilization, chemical disinfectants, filtration, and ultraviolet (UV) irradiation. The possible material damage caused by heat sterilization, in addition to the shortages of consumer chemical disinfectants and filters on the market, poses a critical challenge throughout pandemics leading to demand more sustainable disinfection systems. Disinfection using UV radiation has been a fast-growing chemical-free technology over the past decades. UV radiation is highly efficient at controlling microbial growth in any medium, such as water and air, as well as on any type of surface. (Shining a light on COVID-19, 2020)

UV-C range has a more detrimental effect on microbial cells occurs because the intercellular components of microbes (e.g., RNA, DNA, and proteins) can sensitively absorb UV-C photons. Absorbed UV-C photons cause critical damage to the genomic system of microorganisms (nucleic acid and microorganismal proteins), preventing them from replicating and surviving. (Bolton, 2008) Microorganisms, however, absorb only a small part of the radiation. The predominant part of the radiation is absorbed by the surface of the material. Quantities of near UV radiation (400 – 290 nm) have energies from 3.1 to 4.3 eV, which corresponds to 72 – 97 kcal / mol. This means that these UV have enough energy to break most chemical bonds. (Ranby, 1989)

UV irradiation is known to cause degradation of materials that are irradiated (i.e., polymers). Such degradation can dissociate the material structure and reduce the lifetime of the irradiated material by creating radicals on the surface. Therefore, the applied dose of UV-C energy should be balanced to achieve acceptable levels of biocidal efficacy and avoid excessive energy that would damage the surfaces throughout the anticipated lifetime. (Jo et al., 2019)

2 MATERIALS AND METHODOLOGY

The effect of UV-C radiation on polyamide - PA410 and polyphthalamide with glass fibre (30% of volume) have been studied in this investigation. The samples were produced by injection moulding BOGE Elastmetall Slovakia according to the parameters recommended by the granulate manufacturer. The resulting samples corresponded to the parameters for the type B test specimen determined by the standard STN EN ISO 3167: 2014 - Plastics, Multipurpose test specimens.

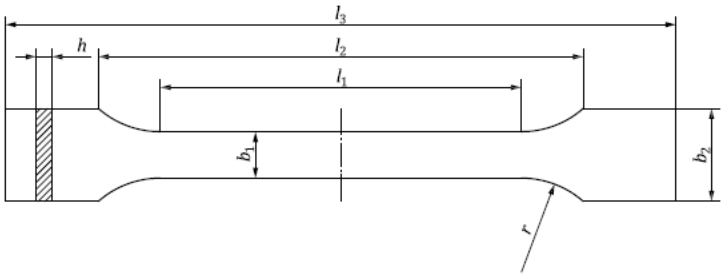

Fig. 1 – Shape of type B test specimen. Source: STN EN ISO 3167: 2014

Tab. 1 – Dimension of type B test specimen. Source: STN EN ISO 3167: 2014

l_3	Overall length	150 mm
l_1	Length of narrow parallel-sided portion	60 mm
r	Radius	60 mm
l_2	Distance between broad parallel-sided portions	110 mm
b_2	Width at ends	20 mm
b_1	Width of narrow portion	10 mm
h	Thickness	4 mm

UV-C exposure

The UV ageing has been carried out in a UV chamber (Figure 3). Samples were irradiated for 72 hours (3 days), 168 hours (7 days) and 336 hours (14 days). The ageing proceeds under a temperature of 50 °C. As a source of UV-C radiation, we used four germicidal fluorescent lamps Philips TUV 15W. The efficiency of the fluorescent lamp was 32%. UV-C radiation reached a power of 4.9 W.

Fig. 2 – Digital model of UV chamber. Source: own research

Discolouration analysis

The 3nh NR200 colorimeter was used to determine the colour change before and after UV exposure. This colorimeter uses D65 light source and works in CIE L^* a^* b^* colour space. Ten measurements were performed on each tested sample.

The CIELAB, or CIE L^* a^* b^*, system is a three-dimensional colour-space consisting of three axes. The L^* axis is a grayscale with values from 0 (black) to 100 (white). The a^* is the red/ green axis; positive and negative a^* describe red and green values. The b^* is the yellow/ blue axis; positive and negative b^* describe the yellow and blue values. (Azevedo et al., 2013)

The composite colour difference is denoted by ΔE^*_{ab}, which accounts for the changes of L^*, a^*, and b^* components, which can be calculated using the equation:

$$\Delta E^*_{ab} = ((\Delta L^*)^2 + (\Delta b^*)^2 + (\Delta a^*)^2)^{1/2} \quad (1)$$

ΔE^* value greater than one indicates colour difference observable by the human eye (Gunasekaran et al., 2007). The human eye is only capable of detecting colour differences at certain thresholds. The minimal detectable difference is anywhere from 1 – 2.5 ΔE^*_{ab}.

The Shore Hardness

The Shore Hardness is a characteristic value that is used predominantly for elastomers, soft rubbers, and very soft plastics. The digital durometer for Shore D hardness with a static pressing load of 5 kg was used. Samples were measured before and after exposure to UV-C radiation according to ISO 868. On each tested sample were performed 10 measurements. The measuring time lasted 15 seconds, after its expiration we recorded the measured value.

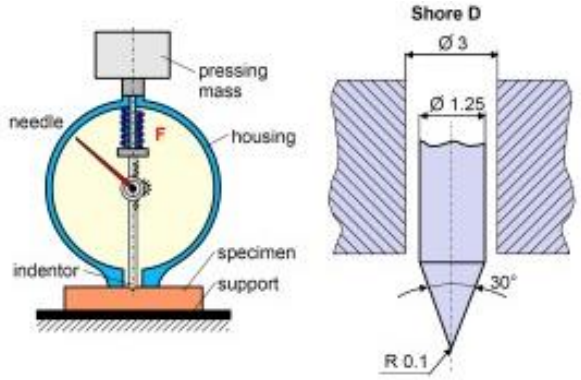

Fig. 3 – Hardness tester for Shore A and D as well as the Shore Indenter. Source: Arndt, 2021

3 RESULTS AND DISCUSSION

Discolouration analysis

All samples underwent an apparent colour change that was visually perceived as darkening. The ΔE value indicated the degree of colour change between two colours, which was increased in the untreated and treated samples were greater than 2.5 in all cases. The change was more pronounced after each time interval.

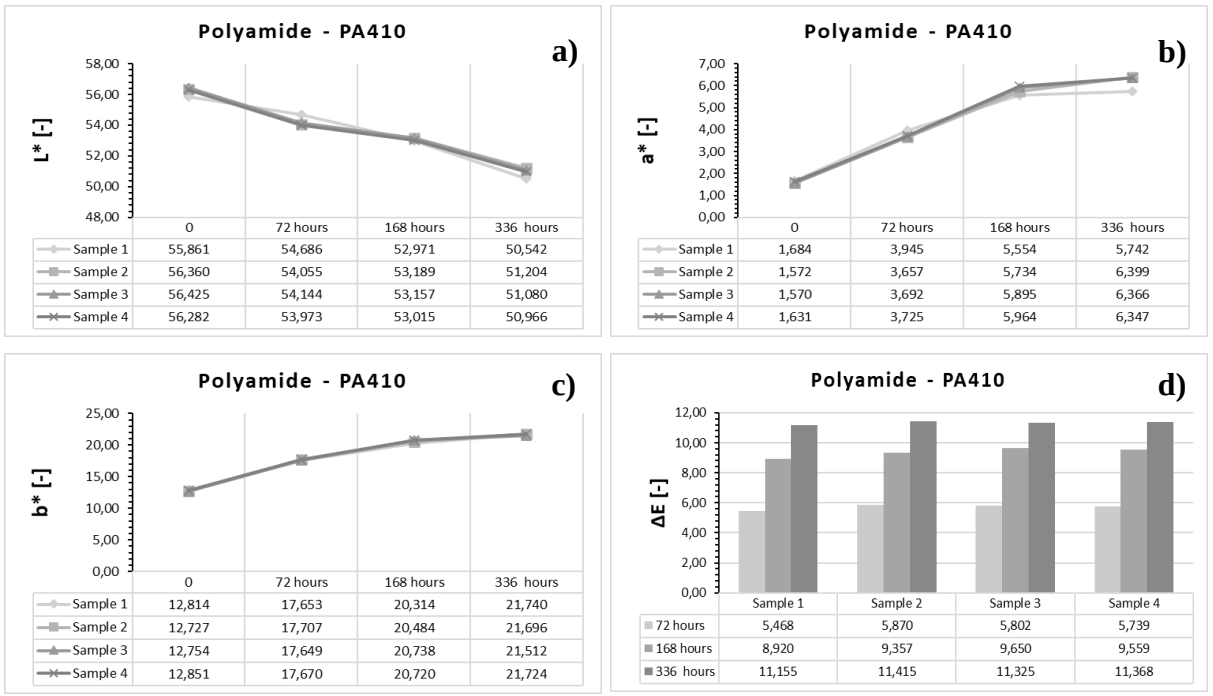

Fig. 4 – Change in colour parameters of Polyamide (PA410) after UV-C exposure. Source: own research

Figure 4 shows the effect of UV radiation on polyamide samples. There is a change a change in all monitored colour parameters in time. *L** represents greyscale and with decreasing value is colour of the sample darker. **a*** represents the green-red scale and increasing value represent increase red colour tone in overall colour. *b** represents the blue-yellow scale and increasing value represent increase yellow colour tone in overall colour. If *ΔE** value is overcome by 2.5 it indicated a colour difference can be observable by the human eye.

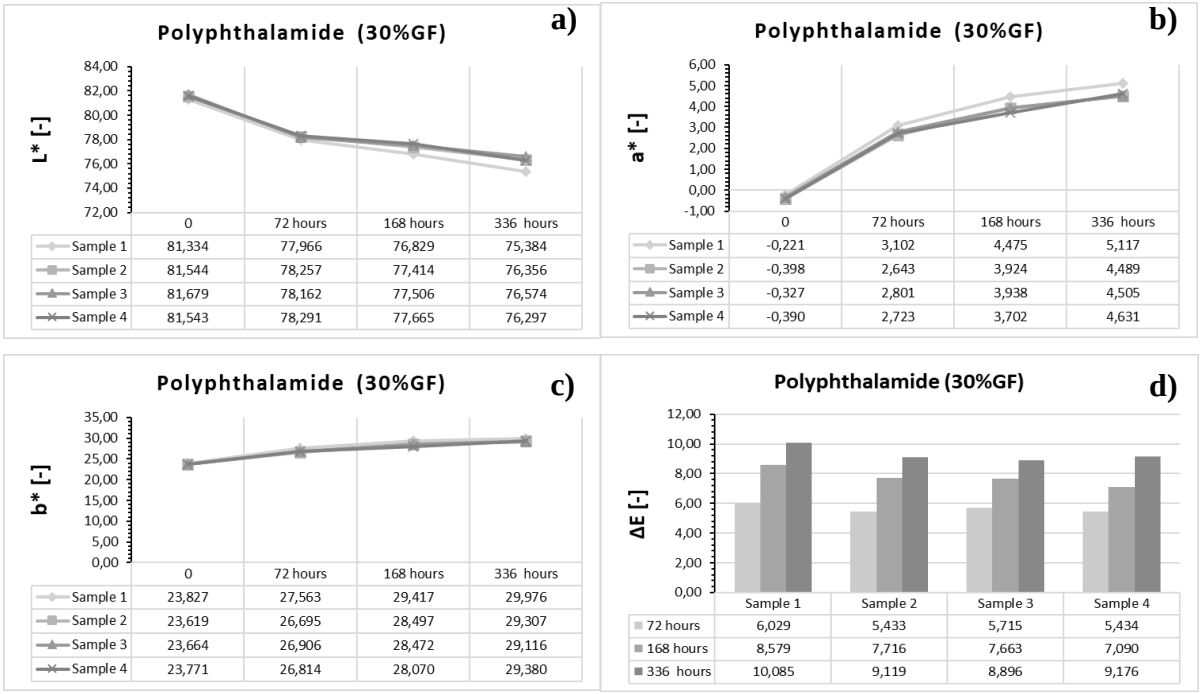

Fig. 5 – Change in colour parameters of Polyphthalamide (30%GF) after UV-C exposure. Source: own research

Figure 5 shows the effect of UV-C radiation on polyphthalamide samples. There is a change in all monitored colour parameters in time. *L** represents greyscale and with decreasing value is

colour of the sample darker. *a** represents the green-red scale and increasing value represent increase red colour tone in overall colour. *b** represents the blue-yellow scale and increasing value represent increase yellow colour tone in overall colour. If *ΔE** value is overcome of 2.5 it indicated a colour difference can be observable by the human eye.

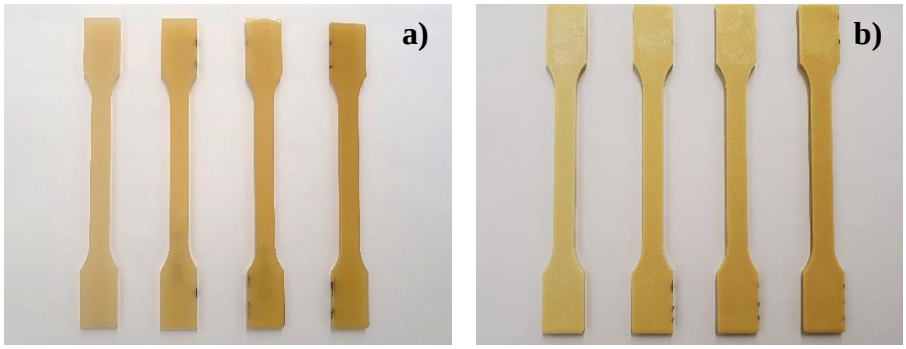

Fig. 6 – Visual comparison of samples a) Polyamide (PA410) b) Polyphthalamide (30%GF). Source: own research

Figure 6 shows a visual comparison of samples exposed to UV-C radiation with a reference sample. As the exposure time increases, there is a visible colour change to brown tone. This colour change can be ascribed to oxidation reactions which lead to the formation of an oxidized layer on the polymer surface. These observations correspond with other researchers. Rek and Bravar (1983) have shown the formation of an oxidized structure for aged polyurethane following UV irradiation. Recently, Rosu et al. (2009) have shown that the oxidation reaction in the backbone of the polyurethane causes yellowing phenomena. In fact, irradiation modifies physical and chemical characteristics of PU surface and results in rapid colour change and degradation. Woo et al. (2007) have shown that UV-exposure darkens the colour of certain composites.

The Shore Hardness

Hardness values (Figure 7) show a little increase owing to the exposure to UV in both materials. There is an almost linear hardness in relation to the exposure time. All samples made of polyamide show the same pattern in hardness increasing. All samples made of polyphthalamide show a very similar pattern of increasing hardness, despite a slight difference in growth. This is most likely due to the glass fibre content and its orientation at the measurement site.

In the case of polyamide samples, after 336 hours of exposure to UV-C radiation, the hardness increased in the range from 3.3 to 5.9%. In the case of polyphthalamide samples hardness increased in the range from 0.8 to 1.4%.

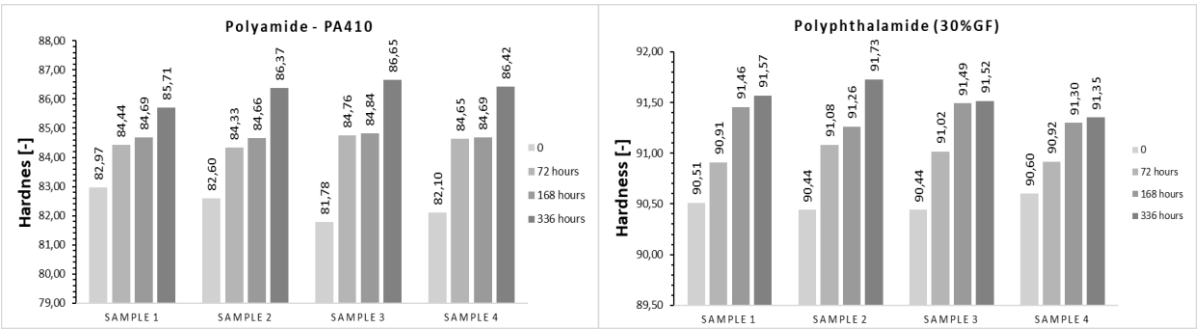

Fig. 7 – Effect of UV-C radiation on hardness a) Polyamide - PA410 b) Polyphthalamide (30%GF). Source: own research

It seems that UV-aging at long duration involves additional crosslinking to give a more highly ordered structure. This crosslinking was accompanied by an increase of stability which can enhance the mechanical properties of material. Subocz et al. (1989) showed that the long-term effect of UV lies mainly in the additional crosslinking to form new supramolecular structures with a higher order.

4 CONCLUSION

Ultraviolet (UV) radiation is one of the most destructive. It is very effective in destroying microorganisms, but also affects the properties of surface materials. This study suggests that exposure of polymeric materials to UV-C radiation can cause intense photodegradation damage. This damage was caused mainly on the surface because the penetration capacity of UV radiation is very low. Even after a 72 hour exposure to UV-C radiation, a significant difference in the colour of the samples is visible. This is also confirmed by the total colour difference ΔE^*, which in both cases was higher than twice the limit after 72 hours and increase over time. The hardness of the tested polymers increased with longer exposure. The hardness of the polyamide increased in the range of 3.3-5.9% and the hardness of the polyphthalamide in the range of 0.8-1.4%.

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IDENTIFICATION OF POTENTIAL SYNERGIES BETWEEN LEAN MANUFACTURING TOOLS AND TECHNOLOGIES OF INDUSTRY 4.0

Lucia Grajzová, Samuel Janík, Miloš Čambál, Miroslava Mĺkva

Abstract

Organizations are currently being led to rethink their processes and strategies due to the highly competitive environment and consequences of the COVID-19 pandemic. Lean manufacturing methods have long been a recognized traditional approach to eliminating waste and increasing the efficiency of production processes. The Fourth Industrial Revolution emerged recently and lays the foundations for new technology-based approaches that, when properly implemented, can serve as a direct extension of traditional, established approaches. By identifying interrelationships and effectively integrating Lean Manufacturing methods with Industry 4.0 technologies, organizations will be able to remain competitive in the market while reducing production costs. Many authors of scientific works are trying to identify possible synergies of these selected methods, some opinions agree, and others contradict each other. However, according to the knowledge of the authors of the article, there is no research that would analyse the perception of the potential of this synergy from the perspective of employees of organizations in the Slovak Republic. The aim of the article is to identify potential relationships between selected Lean Manufacturing methods and Industry 4.0 technologies. Based on the results this study could serve as a guide for industries that are in the process of transforming towards a future of smart factories and offers space for further scientific discussion.

Keywords: *Industry 4.0, lean management, manufacturing, lean tools, productivity*

1 INTRODUCTION

In recent years, Industry 4.0 has become one of the most discussed concepts and has gained significant popularity in both academia and industry. This concept may offer solutions to the challenges of constantly achieving competitiveness in industrial enterprises, which requires a continuous increase in productivity, flexibility, but also the right quality in products or services.

Organizations have been using Lean principles, tools for decades to reduce operational complexity and increase productivity. The Lean approach provides the foundation for operational excellence by standardizing processes, introducing a culture of continuous improvement. However, due to the increasing complexity of operations, many organizations have found that Lean Management as such is not enough to solve their operational problems.

By merging modern digital and physical systems as part of the transition to the fourth industrial revolution, organizations can use both Lean and Industry 4.0 concepts to take operational excellence to the next level. In this article, the authors focused on identifying the potential synergy of Lean Manufacturing methods with Industry 4.0 technologies from the perspective of employees of industrial organizations in the Slovak Republic. The research was carried out using questionnaire survey method and analysed sample was collected from 200 medium and large industrial enterprises in Slovakia. The purpose of this research is to identify the current use of Lean Manufacturing methods in organizations and subsequently identify the potential synergy of Industry 4.0 technologies with Lean Manufacturing methods.

2 THEORETICAL BACKGROUND

A highly dynamic competitive environment leads industrial organizations to constantly re-evaluate their processes and strategies (Valamede & Akkari, 2020). Globalization, strong competition, rapid changes in consumer preferences, as well as ever-evolving trends are pushing businesses to increase their flexibility to respond immediately to these trends and to develop the ability to produce products that would satisfy customers (Pavlovic et al., 2020).

This continuing effort for higher efficiency and flexibility is supported by the Lean concept (Pavlovic et al., 2020). Lean Manufacturing methods are a widely accepted traditional approach to eliminating waste and streamlining production processes (Valamede & Akkari, 2020). Lean is considered one of the most efficient production concepts and has found widespread application in industrial organizations around the world. The core of the concept is to reduce waste in processes, which increases efficiency and reduces production costs (Erboz et al., 2017).

The goal of Lean Manufacturing is to add value by minimizing waste or loss of material, time, space, and people. Production systems combined with this concept include the so-called just-in-time (producing flexibly so that the product is delivered when it is needed and not in order in stock), supply flow management, material resource planning, and zero failure (Armstrong & Taylor, 2020). Lean Manufacturing represents a range of methods that focus on increasing production efficiency, reducing time and cost while maintaining the same product quality (Prabhu & Rajenthirakuma, 2017).

Adopting the Kaizen philosophy with other Lean Manufacturing methods could bring continuous improvement with a focus on eliminating waste. In fact, the phrase "the long journey begins with a small step" clearly illustrates the meaning of Kaizen. All changes must be progressive and begin with a decision after which there is no going back (García-Alcaraz et al., 2017).

In recent years, a new paradigm of Industry 4.0 has been defined, the so-called fourth industrial revolution with the potential to take production processes to the next level (Pavlovic et al., 2020). Industry 4.0, as a counterpoint to the usual methods, brings new technological approaches for organizations. By integrating these two philosophies, especially into manufacturing organizations, it is possible to achieve strategic goals, reduce costs and increase competitiveness (Valamede & Akkari, 2020). Industry 4.0 enables the creation of a smart network of machines, products, components, properties, and systems throughout the value chain, thus forming a smart factory. The main goal of these approaches is to increase productivity and flexibility (Pavlovic et al., 2020).

Industry 4.0, as a technology strategy initiated by the German government, is changing the way products are produced using the advancement of the Internet of Things (IoT) and information and communication technologies to integrate digitization into the production process (Drath & Horch, 2014). "We've seen what happens when 3 billion people come together, we'll see." what happens when 20 billion machines are connected"(Comstock, 2016). For the first time in the digital age, sensors are cheap and powerful enough, clouds are able to send, receive and process huge amounts of data fast enough, and software is smart enough to draw and evaluate conclusions from real-time data. These technological innovations form the basis of Industry 4.0 (Drath & Horch, 2014).

Pabbathi (2018) defines Industry 4.0 as the fourth industrial revolution regarding the intelligent industry focused on the production of intelligent devices and intelligent processes. It is a combination and grouping of many IT technologies, processes, and machines for faster operations, it also reduces the need for time, unnecessary work and enables more efficient decision-making in industrial operations.

Industrial organizations urgently need to respond to current trends and predict future ones. The implementation of technologies in line with trends develops the ability to produce highly customized products to meet rapidly changing consumer preferences while maintaining competitiveness (Sanders et al., 2017). Industry 4.0 is a new approach that uses computer systems and the Internet of Things (IoT) to implement human-machine interaction in manufacturing industries. Unlike the implementation of traditional Lean tools, organizations now tend to make more use of intelligent systems to reap the benefits of the Fourth Industrial Revolution (Erboz et al., 2017). Industrial companies are looking for effective ways to effectively integrate Industry 4.0 concepts into existing processes. This is where a complex problem arises that needs to be analysed and understood. The principles of Lean Manufacturing seek to reduce complexity, while Industry 4.0 increases complexity. On the other hand, Industry 4.0 can also be seen as supporting the concept of Lean Manufacturing, as the evolving transparency due to the introduction of intelligent network systems will contribute to a fundamental process of continuous improvement (Sanders et al., 2017).

The method of production of products will undergo a substantial change in the near future. People, machines, and devices will communicate and influence each other. Businesses should not only focus on becoming an "Industry 4.0 enterprise" but also continue to remain a competitive enterprise in the Industry 4.0 environment (Sakál & Halászová, 2020). Lean Manufacturing is generally considered a potential methodology for improving productivity and reducing costs in production organizations. Industry 4.0 makes businesses intelligent by applying advanced information and communication systems, technologies for the future. The Lean and Industry 4.0 philosophies complement each other and can provide production or plant managers with an overview of achieving a higher level of production efficiency. Many call it "Lean Industry 4.0", "Lean digitization" or "Lean automation".

3 METHODOLOGY

To identify the relationship between Lean Manufacturing and Industry 4.0, we chose a questionnaire survey, which also revealed to us the extent to which industrial enterprises in Slovakia use Lean Manufacturing methods.

Based on the research problem, we set research questions:

V01: „Which of the following Lean Manufacturing methods are used in your company?"

V02: „Which of the Lean Manufacturing methods, combined with Industry 4.0 technologies, can ensure greater production productivity?"

V03: „Can examining the connection of TPM with Industry 4.0 technology contribute to increasing production productivity?"

We further investigated these through a questionnaire survey in industrial enterprises in Slovakia. Distribution was selected via Google Form - Questionnaire, 200 E-mails were sent to medium and large industrial organizations in Slovakia. In order to maximize the effective return of the questionnaire survey, we selected an internal database of industrial companies that work closely with MTF STU. This method of distribution was determined mainly for the pandemic situation in Slovakia due to the SARS-CoV-2 pandemic and also for time efficiency. Data collection took place during the time horizon: 01.03.2021 to 02.04.2021. After the gradual processing of the questionnaires and the exclusion of incomplete questionnaires, 170 questionnaires were usable. Which represents an 85% return on the questionnaire data collection. The research aimed to find a Lean Manufacturing method that, in combination with Industry 4.0 digital technologies, will increase productivity.

4 RESULTS

From the questionnaire survey, which was distributed among medium and large industrial enterprises in Slovakia (Fig. 1), 90 respondents filled in the questionnaire, the number of employees ranging from 250 to 499 employees. The remaining 80 respondents work in an organization with more than 500 employees.

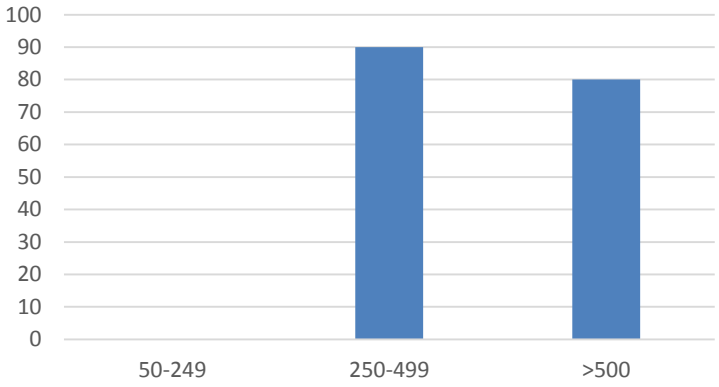

Fig. 1 – Number of employees. Source: own research

Foreign literature lists many methods and tools of Lean Manufacturing. The most common methods that are used in industrial enterprises in Slovakia according to our questionnaire survey are represented in Figure 2.

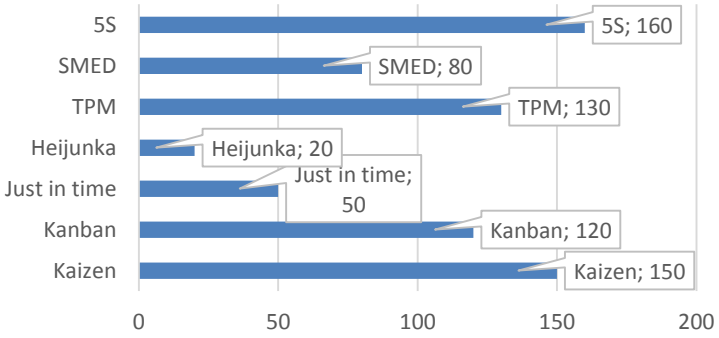

Fig. 2 – Lean Manufacturing methods used in industrial enterprises in Slovakia. Source: own research

Current methods of Lean Manufacturing in industrial enterprises in Slovakia have the strongest representation within the 5S method, the essence of this method lies in organized work, maintaining order, and clarity in the workplace. Right behind it is the Kaizen method, (Boledovič, 2017) an aspect whose origins go back to Japan, it appeals to the continuous improvement of processes. The two main beliefs that tell you how Kaizen works are: (a) everything can be improved, and (b) small frequent changes can lead to significant overall and long-term improvements. The next two methods from the questionnaire are SMED, shortening the recasting times of production equipment, and the Just in time method, which represents the right products or material, in the right quantity, at the right time in the right place. The striking result is in the last place, the use of the Heijunka method, which is used to plan the product quantity and product mix in a certain period of production. Heijunka is based on a certain interval between the dates of shipment of products. At a certain interval, we try to set such a mix of products to cover customer requirements and at the same time to ensure that production is evenly distributed (Sundar et al., 2014). The most important research question was to find

out which of the Lean Manufacturing methods, in combination with Industry 4.0 digital tools, can increase production productivity.

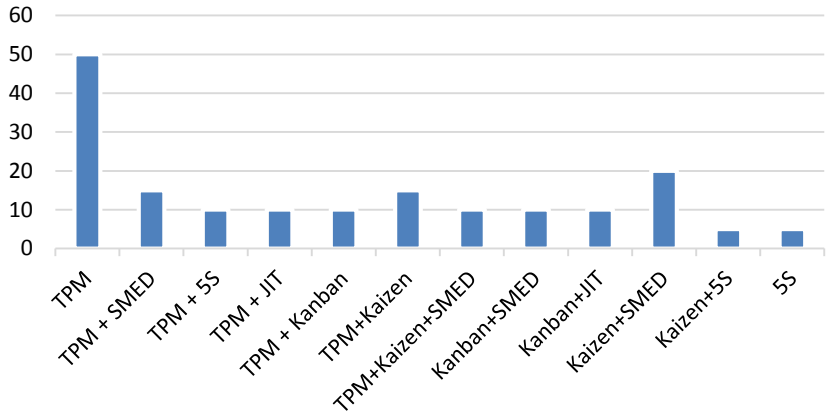

Fig. 3 – Increase productivity with Lean Manufacturing methods in combination with Industry 4.0 digital tools.

Source: own research

Figure 3 shows that the clear winner of increasing productivity for industrial enterprises in Slovakia is the method Total productive maintenance. Out of the total number of respondents, up to 120 respondents mentioned this method. This method is an extremely comprehensive approach to the efficiency of operation and maintenance of equipment. It is one of the basic blocks of any Lean Manufacturing, after all, it is not possible to improve processes if we cannot rely on equipment and machines. Industrial enterprises in Slovakia see the potential in increasing productivity with the Kaizen and SMED methods.

TPM as a key operational function, which is related to all production processes, is used as a strategy to gain a competitive advantage in the industry. Therefore, we asked respondents ,,*Can examining the connection of TPM with Industry 4.0 technology contribute to increasing production productivity?"* The result is shown in Figure 4.

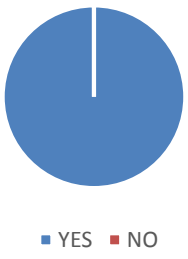

Fig. 4 – TPM links with technology Industry 4.0. Source: own research

The research shows that the respondents were clear on this question, 100% of the answers were directed to the possibility that examining the connection of TPM with Industry 4.0 technology can contribute to increasing production productivity. Based on research questions, we identified the TPM method as a method that correlates with the fourth industrial revolution and from the point of view of employees of industrial enterprises in Slovakia has the greatest potential in increasing production productivity.

From the above analysis, it is possible to note the great impact and compatibility of the TPM method with Industry 4.0 tools. The future of production is based on continuous data-driven improvements. Proven programs - such as TPM, which benefit from continuous improvement

and individual responsibility, is the ideal program for using digital tools that extend maintenance, training, and productivity to meet the pace and demand of Industry 4.0.

5 DISCUSSION

Following the results from the analytical part, we can conclude that enterprises currently perceive the greatest potential for connecting Industry 4.0 with the TPM method in conjunction with the Kaizen philosophy and the TPM tool - SMED. The most commonly used tool for Lean Manufacturing across all enterprises is the 5S method. This method is the cornerstone of a fully integrated TPM system. The results are theoretically understandable given the importance of maintenance as one of the main processes that have an impact on production productivity in industrial enterprises.

The application of Industry 4.0 concepts in correlation with the TPM philosophy is possible through the use of autonomous control, digital imaging, and digital twins of devices and machines that simulate processes, analyse the properties and behaviour of machines and devices throughout their life cycle. Such a synergy of the two philosophies, which in this case serves as an extension to the level of integration of the classic TPM in the enterprise, can have benefits in increasing maintenance efficiency, reducing costs, and increasing the competitiveness of the enterprise.

The 5S method as a basic tool of the TPM philosophy can be systematically improved through Industry 4.0 technologies. With the help of RFID technology, it is possible to identify and locate objects in real-time, thanks to which the time of their search is reduced. With augmented reality, it is possible to visualize predefined locations for tools and navigate operators to their correct locations.

The reasons for the implementation of new technologies can also include the ever-increasing requirements for industrial enterprises in connection with new products in greater variability and with the increased pressure on maintenance, recasting of equipment and machines. SMED is a Lean Manufacturing tool that aims to reduce the time and cost associated with equipment and machine setup processes is a suitable candidate for integration with new Industry 4.0 technologies. By using additive manufacturing as a more efficient alternative to traditional manufacturing, it is possible to effectively eliminate the waste time caused by waiting for the machine to be recast. In additive manufacturing, the times required to change equipment are minimal compared to traditional manufacturing, as the processes are not product-specific. Such a process does not require any special tools for setting up the assembly process for the production of the product and can save time and maintenance costs.

With advancing automation, the importance of performing autonomous controls and digitizing processes across the organization grows. New ways to control equipment and machines are supported by Industry 4.0 technologies as progress in maintenance towards more sophisticated technologies for monitoring the condition of equipment and machines continues. Given the advanced available technologies, organizations need to set specific goals and implementation plans based on the results of analysis: identifying waste in processes, defining the technical condition of equipment and machinery, and defining responsibility for their condition. All processes that will take place during the implementation plan should have defined employees responsible for the implementation of the change and these changes should be covered by the necessary resources for their implementation. The whole process should not be sudden but gradual and based on the Kaizen philosophy - small and frequent changes that have the potential to be big in the future.

6 CONCLUSION

Digitization is a key factor for the future prosperity of organizations and based on the findings of this article, we can conclude that organizations want to change the current paradigm of thinking and move toward the opportunities offered by Industry 4.0 technologies. A turbulent business environment requires innovation to ensure a strong competitive position in the market. Innovative changes are needed today more than ever due to the COVID-19 pandemic. Therefore, it is appropriate to build on the established principles of Lean Manufacturing in the organization, intensify them and gradually build with the use of Industry 4.0 technologies.

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MEASURING THE CUTTING GEOMETRY OF SOLID MILLING TOOLS USING AN OPTICAL 3D SCANNER

Jakub Hrbál, Ján Milde, Ivan Buranský, Jozef Peterka

Abstract

Grinding is one of the basic stages of the production of cutting tools. After manufacturing the tool, it is necessary to check its geometry. The use of a suitable tool geometry ensures the correct machining operation. The geometry of the tool affects the cutting forces, tool wear, chip formation, and the achieved quality of the machined surface. The paper deals with the measurement and control of the produced geometry of the cutting tool. Five solid milling tools were manufactured for the experiment. The tools were made on a WZS 60 Reinecker grinding machine by company ULMER WERKZEUGSCHLEIFTECHNIK. Software NUMROTOplus by company NUM was used to create NC code for grinding machine. Software NUMROTOplus allows to export a cutting tool model in STL format. This model will be used as a nominal model in the evaluation of manufactured tools in GOM software. The geometry of the cutting tools was measured on a structured 3D scanner GOM ATOS II TripleScan by a ZEISS company. The measured parameters were tool diameter, core diameter, relief angles, and rake angles. The measurement results were evaluated using GOM software. Using a colour map of deviations, a difference in geometry was observed between the individual cutting tools. It was observed that the largest deviations were in the rake angle and relief angles.

Keywords: *optical 3D scanning, cutting tools, grinding, tool geometry*

1 INTRODUCTION

One of the modern methods of manufacturing cutting tools by grinding is the use of CNC tool grinders. Modern, commonly used 5-axis CNC tool grinders enable point interpolation of points in all 5-axes, which ensures sufficiently precise guidance of the grinding wheel along the given machining path of the manufactured tool. Using CNC tool grinders, it is possible to produce various complex tools.

In the grinding of its manufacturing, grinding wheels are worn out gradually with the grinding number increasing, resulting in the grinding error. The shape and amount of material removed from the blank corresponds to the shape of the surface of the package, which is the result of the relative movement between the grinding wheel and the workpiece. The main problem of grinding operations is the achievement of the desired shape cutting tool because operations are characterized by complex contact between the blank and grinding wheel. (Karpuschewski et al., 2011)

A three-dimensional optical scanner acquires geometry data from an existing physical object. This data is used to construct a virtual three-dimensional model of the scanned object. Polygonization gives a polygonal mesh that describes the surface. Polygonal mesh can be exported to several standard formats, such as STL, G3D, JT Open, ASCII and PLY. This model can be used for various applications, such as reverse engineering, rapid prototyping, quality management, inspection and 3D printing. (Brajlih et al., 2011)

2 LITERATURE REVIEW

Liu et al. (2019) proposed an error compensation method by considering a boundary condition determination of a worn wheel based on an iteration-based calculation of position and orientation of grinding wheel. The boundary contact condition between the cutting tool and wear wheel was established by identifying the relevant tool profiles associated with the worn and unworn parts of the grinding wheel.

Uhlmann and Hübert (2011) also dealt with the grinding of the flute. The flute grinding operation was analysed using a kinematical simulation to acquire an insight into the local distribution of the material removal rate or the microscopic chip parameters. The investigations cover the cutting-edge quality emerging in characteristic tool grinding operations on end mills.

Peterka et al. (2020) dealt with the production of cutting tools for machining difficult-to-machine materials. A CNC grinder was used to produce cutting tools. The geometry of the cutting tools was checked using a Zoller Genius 3s optical measuring device.

3D scanning is used in several areas of industry. In this case, it can also be applied to check the geometry of cutting tools. In the field of science and research, we know several authors who have already dealt with similar issues. Vagovský et al. (2015) focused-on possibility of measuring a small object, namely hard metal rod which is a semi product for cutting tool, e.g., end mill. In This research authors focused on evaluation of the measuring capability of the optical 3D scanner GOM ATOS II TripleScan when measuring the dimensions, i.e. tool diameter, with using of different measuring volumes.

Peterka et al. (2013) concrete on 3D scanning process of chosen individual object. The problems that occurred during 3D digitizing of individual parts are step by step discussed and solved. This research deals with 3D scanning of ball nose end mills and screw drill. The article gives a procedure for digitizing and comparing the results of the scanned digital models of the two ball nose end mills and screw drill.

Valerga et al. (2016) reports on the results of a preliminary study on the application of different 3D-S and AM technologies for generating VM and PHSM of a two edges mill. A comparison based on cost, result, difficulties-capabilities, and runtime has been made.

Hawryluk et al. (2020) focus on problems related to the use of non-contact 3D scanning techniques and their support by means of replication methods for the analysis of the geometrical changes in deep tool impressions used for the forward extrusion of valve-type elements assigned for motor truck engines.

Alabdullah et al. (2016) investigated tool wear and geometry response when machinability tests were applied under milling operations on the Super Austenitic Stainless Steel alloy AL-6XN. Authors used in the experiment two cutting speeds, two feed rates, and two depths of cuts. Cutting edge profile measurements were performed to reveal response of cutting-edge geometry to the cutting parameters and wear. For inspection of the cutting edges authors used a scanning electron microscope (SEM). Results showed the presence of various types of wear such as adhesion wear and abrasion wear on the tool rake and flank faces.

Čerče et al. (2015) focus on innovative and reliable direct measuring procedure for measuring spatial cutting tool-wear with usage of laser profile sensor. Authors say that technique provides possibility for determination of 3D wear profiles, as advantage to currently used 2D techniques. The influence of the orientation of measurement head on the accuracy and the amount of captured reliable data was examined and the optimal setup of the measuring system was defined. Authors investigated that novel tool-wear and tool-life diagnostic represent objective and robust estimator of the machining process.

Thakre et al. (2019) present in their research a development of machine vision system for the direct measurement of flank wear of carbide cutting tool inserts. This system consists of a digital camera to capture the tool wear image, a good light source to illuminate the tool, and a computer for image processing. The vision system extracts tool wear parameters such as average tool wear area, wear width and tool wear perimeter. The results of the average tool wear width obtained from the vision system are experimentally validated with those obtained from the digital microscope. An average error of 3% was found for measurements of all 12 carbide inserts.

Sandak et al. (2011) focus on measurement of the cutting tool edge recession with optical methods. The goal of authors work was however to design and verify novel optical instruments (such as laser micrometre and triangulation scanner) in scrutinizing of tool wear and scanning of the cutting tool geometry.

3 METHODOLOGY

The aim of this experiment is to use an optical scanner to check the geometry of the manufactured tools. The experiment consisted of two parts: the production of cutting tools and the scanning of the manufactured tools.

3.1 Grinding cutting tools

The cutting tool characteristics are extremely important in the process of machining. Design, geometry, type, and material of the cutting tool are important parameters that directly affect the cost and the quality of the product. The geometry of the cutting tool affects the cutting forces, the wear of the cutting tool and the surface roughness (Grigoriev et al., 2019). The tools were made using Reinecker WZS 60 grinding machine by company ULMER WERKZEUGSCHLEIFTECHNIK. The cutting tools were produced of cemented carbide. The round bar had dimensions Ø10h6 x 73 mm. The grade of cemented carbide was K20-K40 by ISO. The properties of cemented carbide are shown in Tab. 1. The material is used to produce high-performance tools.

Tab. 1 – Basic properties cutting material. Source: Ceratizit (2019)

Density [g.cm^{-3}]	Hardness HRA	Binder [m %]	Transverse rupture strength [MPa]
14.10	91.70	12.00	4000

Software NUMROTOplus was used to create NC code for grinding machine. The 2D and 3D simulation is an integral part of NUMROTOplus 2018. The software is equipped with integrated collision control and provides a complete simulation of the grinding operations. Software NUMROTOplus allows to export a cutting tool model in STL format. This model will be used as a nominal model in the evaluation of manufactured tools in GOM software. Fig. 1 shows geometry milling tool.

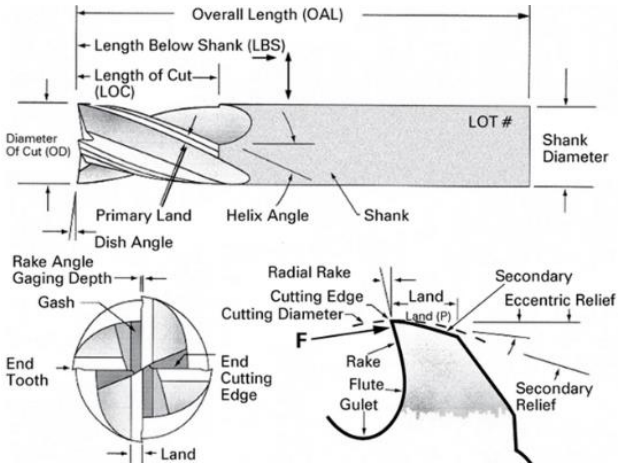

Fig. 1 – The geometry milling tool. Source: Destiny Tool (2021)

For manufacturing milling tools were used grinding wheels with a designation 1V1, 11V9 and 12V9. The geometric shape and dimensions of the grinding wheels are standardized. The grinding wheel 12V9 was used for the operation Tip gash out. The grinding wheel 1V1 was used for the operation Flute of the tool. The grinding wheel 11V9 was used for the operations relief angles 1, 2 and 3. The grinding wheels were manufactured from synthetic diamond with a grain size was from 50 to 62 μm. Tab. 2 shows basic properties grinding wheels.

Tab. 2 – Basic properties grinding wheels. Source: Urdiamant (2007)

Grain size	D 64
Application	For medium grinding and cutting tools sharpening
Surface roughness Ra [μm]	0.40
Amount of abrasive [g.cm^{-3}]	0.88
Type of bond	Resinoid
Abrasive concentration	K 100
Cooling	Yes

3.2 Optical 3D scanning of milling tools

Experimental work was carried out at the Centre of Excellence of Five-Axis Machining at the Faculty of Materials Science and Technology in Trnava, the Slovak University of Technology in Bratislava. The measurement of geometric parameters of the produced milling tools was performed by the 3D scanning process using the ATOS Triple Scan optical scanner, which enables the generation of 3D models of measured objects in the STL format. Subsequently, these 3D models were measured and compared to the nominal model of the measuring software GOM Inspect 2020. 3D scanning of the milling tools took place at a measuring volume of MV100. Tab. 3 shows parameters of ATOS scanner.

Tab. 3 – Parameters of ATOS scanner. Source: own research

Camera resolution	**Measuring volume MV100 (LxWxH) [mm]**	**Measuring point distance MV 100 [mm]**
5 megapixels (2448 x 2050 pixels)	100 x 75 x 70	170 x 130 x 130

Before measurement, the individual tools were degreased and sprayed with titanium powder using a special pneumatic pump. By using titanium powder, the tools get a matte surface. However, only a very fine layer of powder was used to make the effect of the powder on the measurement result negligible. The tool was clamped in a three-jaw chuck. A fixture was attached to the chuck. The circular reference points with a diameter of 0.4 mm were placed on the attached fixture. These measuring points are used to connect the individual measurement

images and at the same time increase their accuracy. Fig. 2 shows scanning the milling tool using an optical 3D scanner GOM ATOS II TripleScan.

Fig. 2 – Scanning the milling tool using an optical 3D scanner GOM ATOS II TripleScan. Source: own research

Before the measurement, it was necessary to calibrate the measuring device. Calibration must also be performed every time the measuring volume is changed, omitting the calibration would result in a reduction in accuracy. Scanning was performed on a rotary table. The tools were scanned in two positions as shown in the Fig. 3. The number of recorded images per table rotation was set to 32. This number can be different, but the more rotations, the more data we get about the scanned object. For complex objects with different rounding or sharp edges, it is advisable to use a larger number of rotations. At these parameters, data were obtained from all 5 manufactured tools. The measurement output was a polygonal 3D model of individual milling tools, which were exported from the ATOS Professional system in STL format.

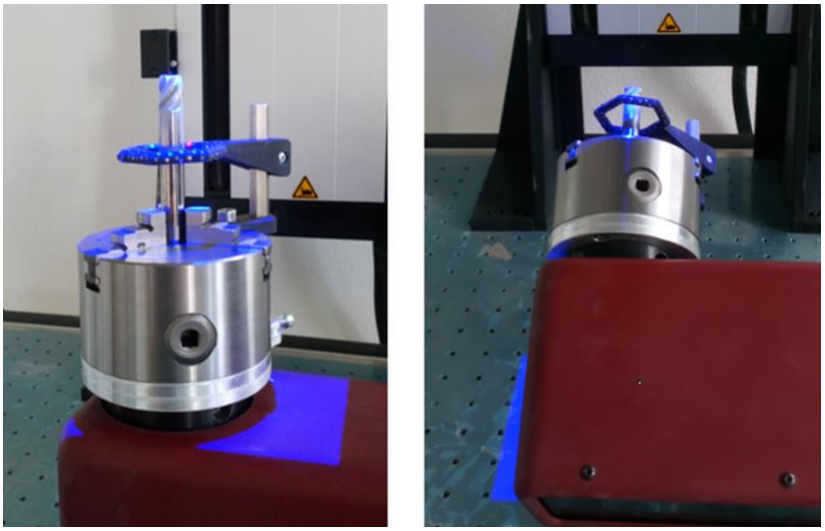

Fig. 3 – Cutting tool scanning position. Source: own research

4 RESULTS

The measurement of geometric parameters was performed with the measuring software GOM Inspect 2020. It is software designed for the analysis of 3D measured data of projection measurement, laser scanners, coordinate measuring machines, and other measuring systems. In

practice, it is used mainly in product development, quality control, and production. The software is also able to calculate from the 3D point cloud a 3D mesh of a given component, which can then be smoothed out, in addition, it is also possible to fill the holes created by the mesh. Such a precise polygon mesh can then be exported to all standard formats.

The calculated polygon mesh describes free form surfaces and standard geometry, which can be compared with a nominal CAD model, where it is possible to implement, for example, 3D analysis of surfaces, but also 2D analysis of sections or points. It is also possible to measure geometric elements such as flatness, parallelism, or cylindricality. Analysis and measurement of two-point distances is also possible.

At the beginning of the measurement, a CAD model of the designed milling tool was imported from the NUMROTOplus software, which was used as a nominal model. Subsequently, a scanned model of the milling tool in STL format was imported, which was first aligned using the "Prealignment" function. The "Local Best Fit" function was used to align the model of the scanned milling tool to the tip and the cutting part. In this way, all 5 STL models of the scanned milling tools were inserted and aligned.

The GOM software is able to use the colour deviation map to determine the difference between the nominal and actual model. Fig. 4 shows a colour map of the deviations of the geometry of the milling tool and the cross section of one tooth of the tool. With the cross section of the tool, the largest deviation is at the cutting edge. The largest deviation was observed in the helix of the cutting tool.

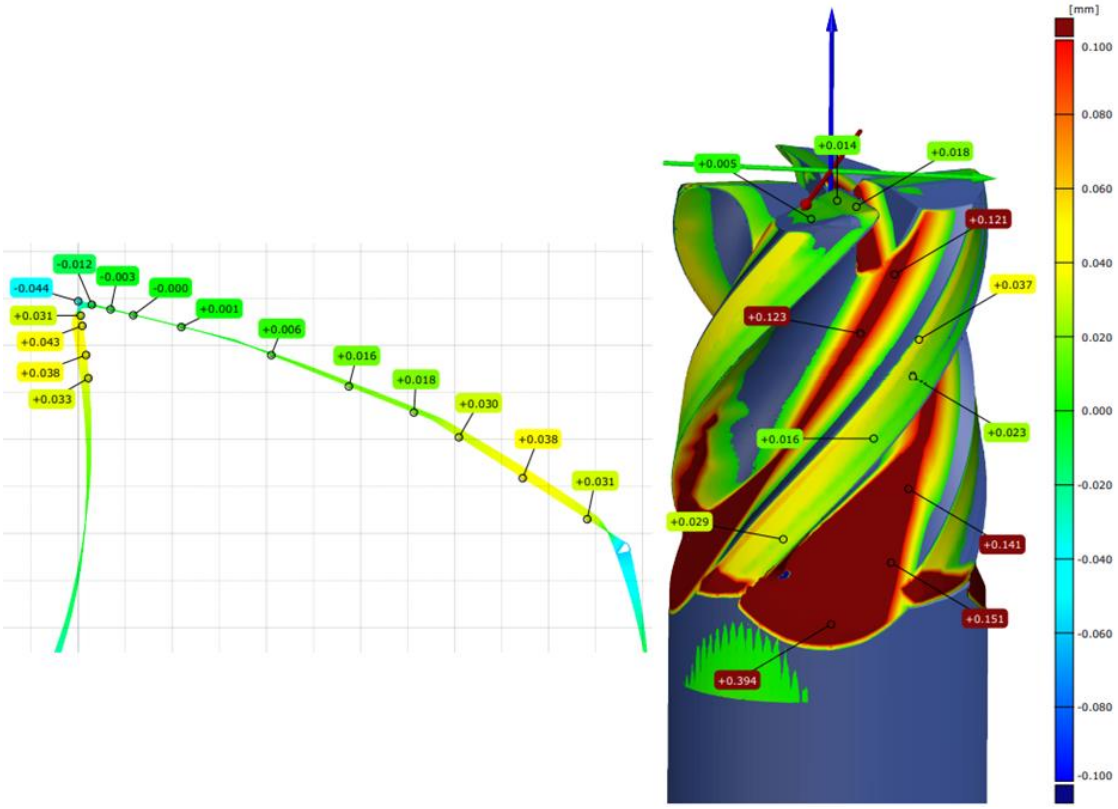

Fig. 4 – Colour map of deviations of one tooth and overall cutting geometry. Source: own research

The face angle, three relief angles, core diameter, and tool diameter were measured on the circumference of the tool. The diameter of the tool and the core were measured using circles created by the "3-point circle" function. The points were placed on the edges of the individual teeth. The diameters were created individually on the nominal and actual model to compare the

measured values. To compare the diameters, it was necessary to link the average of the nominal model with the diameter of the scanned model. Such a link between the individual circles was created using the "Link To Actual Element" function. Fig. 5 shows measuring core diameter and tool diameter.

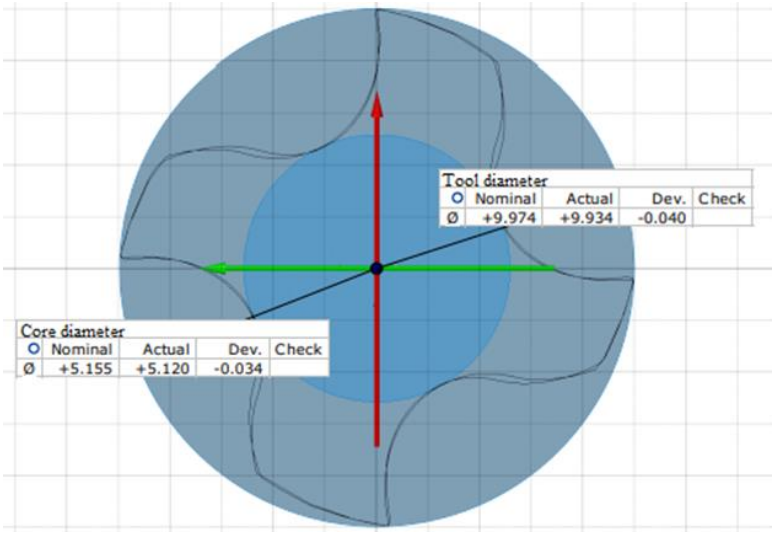

Fig. 5 – Measuring core diameter and tool diameter. Source: own research

Fig. 6 shows the measured values of the individual angles on the tool circumference. Specifically, rake angle and relief angle 1, 2, and 3. Before measuring the angles, it was necessary to create auxiliary lines on the edges of the tool. The "Fitting Line" function was used to create the lines. The measurement was performed on the nominal (blue) and actual (green) models. The angles of the cutting tool were measured using the "2-Directions Angle" function. This procedure was also used to measure the cutting angles at the face of the tool. Fig. 7 shows the measurement of angles at the face of a cutting tool. Relief angles 1, 2, and rake angle were measured at the face of the tool.

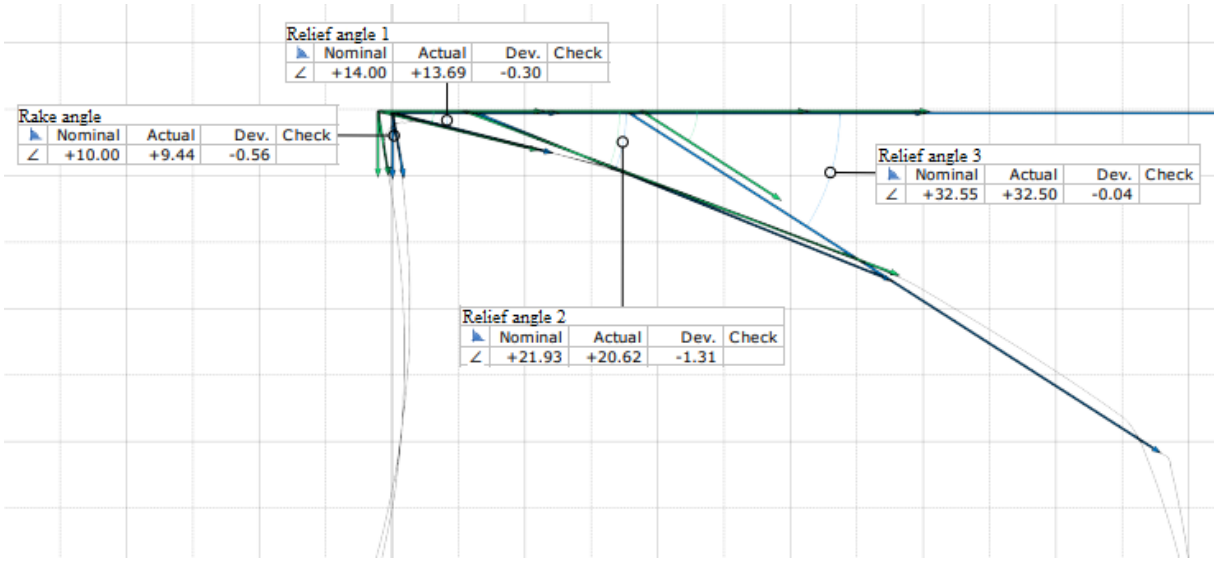

Fig. 6 – Measuring angles on the circumference of the cutting tool. Source: own research

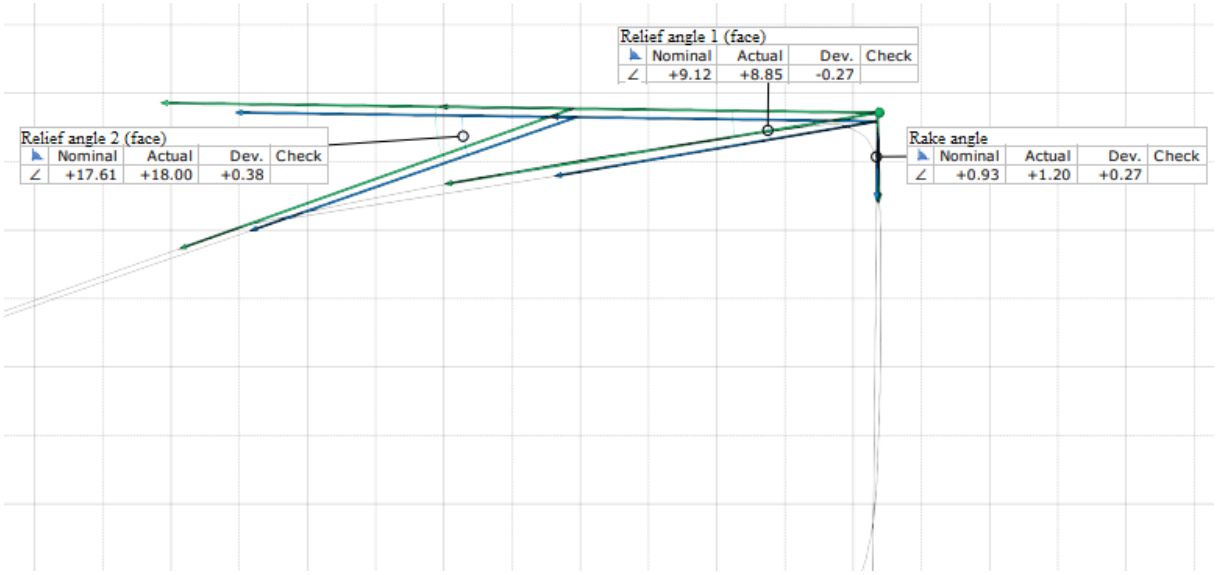

Fig. 7 – Measuring angles on the face of tool. Source: own research

5 DISCUSSION

In this experiment, the macro geometry of cemented carbide cutting tools was compared with a nominal model from the NUMROTOplus software. When evaluating the results, the size of the deviations that arose between the nominal model and the individual 3D scans of the produced cutting tools was monitored. The following parameters were compared - core diameter, tool diameter, rake angles, relief angles on the circumference and face of the tool. The manufactured parts were digitized by optical 3D scanner GOM ATOS II TripleScan. The dimensional and shape accuracy of the parts was evaluated in the software GOM Inspect 2020. Tab. 4 shows the measured monitored parameters of the cutting tools.

Tab. 4 – Measured values of individual milling tools. Source: own research

	Nominal model	**Tool no. 1**	**Tool no. 2**	**Tool no. 3**	**Tool no. 4**	**Tool no. 5**	**Average value**
Tool diameter [mm]	9.97	9.93	9.94	9.96	9.95	9.94	9.95
Core diameter [mm]	5.15	5.12	5.14	5.16	5.13	5.15	5.14
Rake angle [°]	10.00	9.44	9.38	9.36	9.33	9.23	9.35
Relief angle 1 [°]	14.00	13.69	13.77	13.52	13.49	13.54	13.60
Relief angle 2 [°]	20.93	20.62	20.87	20.45	20.34	20.57	20.57
Relief angle 3 [°]	32.55	32.50	32.37	32.60	32.57	32.41	32.49
Rake angle (face) [°]	0.93	1.20	1.11	1.36	1.19	1.03	1.18
Relief angle 1 (face) [°]	9.12	8.85	8.74	8.96	8.88	8.74	8.83
Relief angle 2 (face) [°]	17.61	18	17.71	17.86	17.93	17.53	17.81

Based on the analysis of the measured values of the monitored parameters and the colour map of the deviations of the individual tools, it can be said that there were no significant changes in the monitored geometric parameters between the individual cutting tools. The biggest differences were between relief angle 2 and rake angle. The average value of rake angle was 9.35° and the rake angle on the nominal model was 10° so the difference between the rake angles was 0.65°. The largest deviation in angle measurements was observed at the relief angle 2. Specifically, it was 0.59°. The largest deviation between rake angle (face) was 0.25°. The difference between other parameters was considerably small. Minimal deviations were found when measuring tool diameter and core diameter. Deviations ranged from 0.01 to 0.06 millimetre. The inaccuracy can be caused by abrasion wheel wear, measurement inaccuracy, or a large amount of applied titanium powder.

6 CONCLUSION

Evaluation of the measuring capabilities of a measuring device is very important in ensuring the quality of measurement. The paper presents the use of optical 3D scanning of the geometry of milling tools. Five milling tools were made on a WZS 60 Reinecker grinder. NUMROTOplus software was used to create the NC code for the grinder. The nominal model was obtained from NUMROTOplus software. The nominal model was exported in .stl format, which served as the basic model for comparing scans of manufactured tools. The geometry of the cutting tools was measured on a contactless structured optical 3D scanner GOM ATOS II TripleScan. The measurement results were evaluated using GOM software. The measurements were mainly focused on the accuracy of the produced angles on the face and circumference of the tool. In addition, the core diameter and tool diameter were measured. The largest deviations were observed at the rake angle. The average value of the forehead angle was 9.35° and on the nominal model it was 10. The difference between the inclination angles was 0.65°. The difference between the relief angle 2 was 0.59° and the difference between the face angle (face) was 0.25°. The purpose of the research was to determine the accuracy of the grinder. In the case of core diameter and tool diameter, minimal deviations were observed between the nominal model and the individual scanned tools.

The accuracy of grinding wheels can be achieved by machining and drawing the wheels. Measurement accuracy can be increased by using a smaller measured volume (MV). A smaller measuring volume has a smaller point spacing. A smaller measuring volume has a smaller point spacing. The measuring camera seals more points into a smaller measuring volume and thus increases the accuracy of the measurement. The dependence of the size of the measuring volume on the accuracy of the measurement was confirmed by Vagovský et al. (2015). The dependence of the measuring accuracy of cutting tools on the measuring volume will be the subject of further research. Deviations of individual geometric shapes are relatively small. Deviations can be caused by wear of grinding wheels, uncertainty when measuring the measuring machine. The application of titanium powder did not affect the measurement results. The average thickness of the titanium powder is 5 μm (Palousek et al., 2015). The results show that optical scanning can be used to check the geometry of manufactured tools.

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LITERATURE RISING OF DIGITAL TWIN TREND IN SUPPLY CHAIN AND LOGISTICS

Milena Kajba, Borut Jereb

Abstract

There are many contributions about IT technology trends, that are making their pompous debut in the fields of supply chains and logistics. The increase in interest arose due to the previous research we have conducted that was based on a review of IT technology trends for the past six years. The results of that research have pushed us into deep thinking about the importance of individual trends – why some are more significant than others, especially given what is happening around us. We shifted our focus on one of them: digital twin trend in connection with the supply chain, logistics and its processes or sub-elements. To determine the importance of this trend throughout the years, we focused on researching various publications, articles, papers, presentations, and other contributions on focused topic with the help of two different databases. Comparison and interpretation of the results gave us an insight into the importance of individual searched keywords combinations and consequently into the significance of combinations of studied areas. This research was focused on determining, whether there is a lack of scientific contributions on the topic of digital twins in connections to supply chain, logistics and its sub-elements. The main objective of this paper was to confirm the current and relevant topicality of the topic on digital twin trend in correlation to supply chain and logistics, based on the quantity of scientific contributions, which is shows from the trend of which is confirmed by the exponential increase in contributions publications throughout last years.

Keywords: *review, digital twin, supply chain, logistics, trend*

1 INTRODUCTION

As we know, the supply chain concept is broader than logistics concept, and both cannot function without each other. The importance of this interdependence and relationship was particularly evident in the light of the COVID-19 pandemic, which turned the operations of many companies upside down. Some decided to close their doors due to too many obstacles and challenges, while others attempted to remain above the water and continue their business story. It is true that the pandemic came unexpectedly and left huge consequences, but there has been no shortage of challenges in the business world before. Admittedly, they were smaller compared to the current one, but they were just as important at the time.

Many experts warn that only innovative and flexible companies succeed in today's competitive business world, while not always mentioning how this can be achieved. Of course, there are several ways to present competition to companies in the same industry, and one of them is undoubtedly the monitoring, evaluation, and implementation of IT technology trends. The latter can also represent the difference between business success and failure. But why are they so important?

Throughout past years, we can find various improvements and innovations in every sphere of business that have changed the way we do business and the perception of the world around us. Because of this, companies can say: "We are better! We have new, quality and innovative products that will make your life easier". But at the same time, they could (and may not even think about it), like their customers, make "life easier" for themselves and their company.

The digital age has been with us for some time, and most companies have already shifted their business to digitalisation or even online business – some before the pandemic, some just because of the pandemic. Either way, both were able to realize the benefits and advantages it offers. Technology can reduce the workload of employees in the company, help to process data faster, make it easier to access information in any place for each of the authorized employees, and much, much more. So why not use it to your advantage.

From year to year, we can follow a rise of different contributions that relate to many trends within individual industries or areas of business. Much of the contents is also freely available and why should we not facilitate and even improve our business if the contents are created specifically for that purpose. We are aware that although a wide range of different technological improvements are available, they cannot be introduced everywhere due to possible deficiency of knowledge, which is due to the lack of relevant contributions for a particular field.

As a result of preliminary research, we voiced our thinking about why some IT technology trends are more important than others. Why certain ones are not addressed as much as they could be since their importance in various individual fields is recognized. Thus, we focused to further research one of the IT technology trends in connections to supply chain and logistics, which is the digital twin. We could have dedicated our time on another trend, but the importance of the latter seemed considerable to us, so we focused our research powers on it.

The main objective of this paper is to confirm the current and relevant topicality of the topic on digital twin trend in correlation to supply chain and logistics, based on the quantity of contributions.

2 THEORETICAL BACKGROUND

To be able to respond quickly and adapt to forthcoming events, future systems will have to be more autonomous. Autonomous systems are in other words intelligent machines can decide on their own between variety of alternative actions, orchestrate and perform skill or high-level tasks without both detailed programming and human control (Rosen et al., 2015). Rosen et al. (2015) stated, that in "order to make this happen, the autonomous systems will need access to very realistic models of the current state of the process and their own behaviour in interaction with their environment in the real world". Those are called the "digital twin". The concept of digital twin was originally introduced in 2003 (Grieves, 2014). The public got acquainted with the concepts in 2012 by the NASA (Glaessgen & Stargel, 2012) for monitoring a satellite's behaviour and simulate potential changes in the settings (Grieves & Vickers, 2016).

Before mentioned autonomy has many consequences, one of them being rise of complexity of ensuring the proper system behaviour during production in the desire to reach the production goal. This process can be reasonably achieved, with the help of extensive use of model-based simulation during all phases of life cycle for such purposes such as diagnosis or optimized operations. (Rosen et al., 2015) To facilitate the understanding of this, touching definitions let us look at the definition(s) of digital twins. Some define them as a digital representation of an active unique product, service or production system that is characterized by specific properties or conditions (Schleich et al., 2017) used to understand, analyse, and improve the product or service system or production (Stark et al., 2019). Hartmann and Van der Auweraer (2021) stated that digital twin "integrates all data, models, (electronic) information, and other knowledge of a physical asset generated during its life cycle (from the product definition and ideation to the end of its life) that leverage business opportunities". Furthermore, they stated that the role of digital twin is to "bridge the virtual and real world with aim to model, understand, predict, and optimize their corresponding real assets – thus, simulation and/or data-based methods are used (Hartmann & Van der Auweraer, 2021). Stark et al. (2019) claim that digital twins are "new

solution elements to enable ongoing digital monitoring and active functional improvement of interconnected products, devices and machines". Tao and Qinglin (2019) stated that digital twins represent virtual but a precise copy of machines or systems. Sophisticated computer models imitate almost every aspect of a product, process, or service and are in addition, are driven by data collection from sensors in real time (Tao & Qinglin, 2019). We can say that digital twin itself is only a central asset, if it can be used for relevant predictions and providence of relevant information at the right time (Hartmann & Van der Auweraer, 2021).

Digital twins were originally developed to improve manufacturing processes, but they are being redefined as digital replications of both living and non-living entities. The latter enable data to be seamlessly transmitted between two worlds – the physical and virtual. In addition to all of the above, they also provide continuous feedback to improve quality of life and well-being. (El Saddik, 2018)

Nowadays, digital twins are considered of much importance to business. It is generally accepted that digital twins lead to enormous savings throughout the whole product life cycle and simultaneously enable on-site diagnostics, prescriptive maintenance, or operation optimization (Hartmann & Van der Auweraer, 2021). There are various cases where digital twins are already used in practice "to spot problems and increase efficiency" (Tao & Qinglin, 2019). Digital twins and their related technologies are rising research topic. First experimentation prototypes of digital twins have been built in desire to understand the nature – the power – beyond the conventional analysis of operational data (such as in traditional maintenance, or production in industry) (Stark et al., 2019).

Good practice, for example: NASA monitors the status of its spacecraft by using digital copies. Energy company Chevron tracks the operations of wind turbines with the help of digital twins (Tao & Qinglin, 2019). Digital Twins can help track data of failures throughout the entire course of transport, can help predict failures of each individual vehicle, and can plan the full capacity (Shubenkova et al., 2018). Previously mentioned solutions are especially necessary in complex networks, such as automobile, electric power, supply chains and other industries. Examples of digital twin applications can show how to solve variety of tasks within broad scope of complex systems.

Shubenkova et al. (2018) determined four types of digital twins, based on encompassing the entire value chain: (1) Digital Twin of the product; (2) Digital Twin of production; (3) Digital Twin of performance; and (4) Digital Twin of service. Mentioned examples indicate that digital twins are a potential method to achieve physical and back-end integration of companies. However, despite the availability of considerable size of successfully used digital twins, a methodology is needed. The models could still be developed at the component level, but afterwards combined into simulations at the system level. Lastly, they could be used in variety of applications. (Shubenkova et al., 2018)

Accumulating data from hundreds or even thousands of sensors (which track temperature, speed, power) can de challenging. Also, information can be spread among different owners and consequentially be held in various formats. And let us not forget the most important information about digital twins: each model is built from scratch – there are no common methods, standards, or norms (Tao & Qinglin, 2019). To realize the potential of digital twins – a long road awaits us.

This paper focuses on review of contributions quantity throughout the specified years rather than on literature review. The reason for this is the lack of contributions that explore and prove the topicality of the topic on digital twin trend in supply chains and logistics field, which we have researched with this paper.

3 METHODOLOGY

A preliminary study was carried out by using predictions about IT technology trends by Gartner. The results helped us to determine those trends, that are repetitive, reoccurring, constant, or evolving. This was the basis for further research and a key part for achieving the main objective of this paper – to accumulate a quantity of contributions which confirm the current and relevant topicality of the topic on digital twin trend in correlation to supply chain and logistics, as previously stated. To accumulate the results, we firstly collected data on top strategic IT technology trends from and including 2015 and 2017, and top supply chain IT technology trends from and including 2018 and 2020. To facilitate better understanding, we segmented trends in rows according to similarity and the number of iterations (reoccurrences) over studied years. We arranged them in descending order – at the top of the table were IT trends with most iterations, escalating to the least common ones. We did not take into the account those IT trends, that occurred only once in all six years.

As a result of the aforementioned study, we were interested in how publications, articles and papers on the digital twin trend, in connection to logistics, began to appear through past years. Firstly, we determined the contribution search bases.

We compared queries from Web of Science and Google Scholar. The first provides access to multidisciplinary bibliographic databases with citation indices. It includes data from about 10.000 of the most prestigious and influential scientific journals in the world for the period from 1970 onwards. The latter provides a simple way to broadly search for scholarly literature across a wide variety of disciplines and sources. Thus, we can compare the results of a moulded database and a broad-spectrum database.

We determined a span of researched years - from 2005 to 2020. We excluded the year 2021, because it is not finished yet. The time interval was chosen based on the desire for broad transparency of the digital twin trend.

We chose the keywords by which we conducted our research. We opted for two levels, namely one keyword search and two keyword searches. Level one search was based on keyword "digital twin", as for level two search was based on variety of keyword combinations: "digital twin" AND "logistics", "digital twin" AND "supply chain", "digital twin" AND "manufacturing", "digital twin" AND "production", "digital twin" AND "transport". The choice for two level search was based on the scope of the research, which may be further expanded and continued in the future.

We began with research on Web of Science. We selected to search in "All Databases" with "Basic Search". Then we have entered the first keyword (for example: digital twin) and for "Timespan" picked "Custom year range", where we were then able to enter the desired year to research. As for the search based on two keywords, we have entered the first keyword as before (for example: digital twin), then added a new row, we chose Operator Precedence "AND" (so both keywords would be taken into the account) and lastly, entered the second keyword (for example: logistics). The "Timespan" options remained the same as in search with one keyword.

The second part of the research was conducted using Google Scholar "Advanced search". We wanted to find articles with all the written words, where we entered the first keyword in quotation marks for better search results. In "where my words occur" sections we picked option "anywhere in the article", and lastly in "Return articles dated between" section we entered the desired year to research. As for the search based on two keywords, we only adjusted first section – alongside the first keyword, we added Operator Precedence "AND", with the second keyword (for example: "digital twin" AND "logistics"). We excluded patents and citations from our research. During the research, we entered the results of queries in one Microsoft Excel file: (1)

First column contained search string (keywords); (2) Second column was reserved for researched years (from 2005 to 2020); (3) Third column contained number of queries from Web of Science; and (4) Fourth column contained number of queries from Google Scholar. Furthermore, we created two more tables in separate Microsoft Excel spreadsheets for the purposes of this research, which are presented in the next chapter.

4 RESULTS

As we stated in the previous chapter, the creation of this research paper is based on a previously conducted study where we determined that the digital twin trend occurred infrequently between 2015 and 2020, alongside two other trends: Software applications and architecture and Blockchain. The numbers of iterations of mentioned IT technology trends, was over the span of six years as follows: (i) 2015 to 2017 (three iterations) – Software applications and Infrastructure or Architecture trends; (ii) 2017 to 2019 (three iterations) – Blockchain trends; and (iii) 2017, 2019 and 2020 (three iterations) – Digital twin trends.

It was interesting to see, that digital twin trend occurred only three times in past six years, of which in the last two consecutive years. The importance of digital twins is only growing, therefore we wanted to research how the trend, in connection to the field of logistics, started to appear in the literature from 2005 to 2020. For better transparency, we have created two sub-chapters.

4.1 Query results of Web of Science

One of the created tables in separate Microsoft Excel spreadsheets contains the query results of research from Web of Science. The Tab. 1 represents all researched years with the number of results for keyword searches.

Tab. 1 – Query results for digital twin trend on Web of Science. Source: own research

Year / Keywords	Digital twin	Digital twin, supply chain	Digital twin, logistics	Digital twin, manufacturing	Digital twin, production	Digital twin, transport
2005	0	0	0	0	0	0
2006	0	0	0	0	0	0
2007	0	0	0	0	0	0
2008	0	0	0	0	0	0
2009	0	0	0	0	0	0
2010	0	0	0	0	0	0
2011	1	0	0	0	0	0
2012	0	0	0	0	0	0
2013	1	0	0	0	0	0
2014	1	0	0	1	0	0
2015	2	0	0	0	0	0
2016	5	0	0	0	0	0
2017	29	0	0	11	9	0
2018	95	2	0	26	25	2
2019	348	10	12	99	86	5
2020	987	28	27	178	169	14

We can see that first six rows (from year 2005 to 2010) did not bear fruit as far searches go. In 2011, we have found only one query for keyword “digital twin”. Year 2012 was the same as before 2010, while in 2013 we were again able to find one query for keyword “digital twin”. Search within next year found query for keyword “digital twin” and also a query for keywords “digital twin” and “production”. Years 2015 and 2016 were almost the same as years 2011 and 2013 – in first we found two and in the latter five queries for keyword “digital twin”.

In 2017, queries rose as only three searches (of two combinations of keywords) had zero queries: 29 queries for keyword “digital twin”, 11 queries for keywords “digital twin” and “manufacturing”, and lastly, nine queries for keywords “digital twin” and “production”. Over the following years, the queries have only intensified.

In 2018, only one search had zero queries, as for the others: 95 queries for keyword “digital twin”, 2 queries for keywords “digital twin” and “supply chain”, 26 queries for keywords “digital twin” and “manufacturing”, 25 queries for keywords “digital twin” and “production”, and lastly, two queries for keywords “digital twin” and “transport”.

2019 was the first year, where all combinations had queries, that drastically increased, as follows: 348 queries for keyword “digital twin”, 12 queries for keywords “digital twin” and “logistics”, ten queries for keywords “digital twin” and “supply chain”, 99 queries for keywords “digital twin” and “manufacturing”, 86 queries for keywords “digital twin” and “production”, and lastly, five queries for keywords “digital twin” and “transport”.

Search on Web of Science for the last year, 2020, again drastically increased with some combinations of keywords, as follows: 987 queries for keyword “digital twin”, 27 queries for keywords “digital twin” and “logistics”, 28 queries for keywords “digital twin” and “supply chain”, 178 queries for keywords “digital twin” and “manufacturing”, 169 queries for keywords “digital twin” and “production”, and lastly, 14 queries for keywords “digital twin” and “transport”.

4.2 Query results of Google Scholar

Second created table in Microsoft Excel spreadsheets contains the query results of research from Google Scholar. The Tab. 2 represents all researched years with the number of results for keyword searches.

Tab. 2 – Query results for digital twin trend on Google Scholar. Source: own research

Year / Keywords	Digital twin	Digital twin, supply chain	Digital twin, logistics	Digital twin, manufacturing	Digital twin, production	Digital twin, transport
2005	43	1	0	24	24	5
2006	45	1	1	29	26	12
2007	51	1	1	41	27	6
2008	62	5	3	47	31	15
2009	67	5	2	44	33	16
2010	66	6	6	46	43	17
2011	69	8	11	47	49	15
2012	95	7	7	58	53	22
2013	105	14	9	61	48	30
2014	99	8	6	50	57	21
2015	129	17	22	80	76	39
2016	296	61	47	196	173	68
2017	844	203	195	573	601	245
2018	2.430	535	601	1.560	1.680	661
2019	5.610	1.100	1.170	3.250	3.300	1.570
2020	7.780	2.070	1.870	4.380	5.170	2.610

Unlike the previous table and research, here we have queries for every year. In 2005, we have found only one combination of keywords (“digital twin” and “logistics”) without a query. Other combinations had: 43 queries for keyword “digital twin”, one query for keywords “digital twin” and “supply chain”, 24 queries for keywords “digital twin” and “manufacturing”, and also for “digital twin” and “production”, and lastly, five queries for keywords “digital twin” and “transport”.

2006 was already the first year, where all combinations had queries, as follows: 45 queries for keyword “digital twin”, one query for both keywords “digital twin” and “logistics”, and “digital twin” and “supply chain”, 29 queries for keywords “digital twin” and “manufacturing”, 26 queries for keywords “digital twin” and “production”, and lastly, 12 queries for keywords “digital twin” and “transport”.

In 2007, keyword “digital twin” had 51 queries, keywords “digital twin” and “logistics”, and also “digital twin” and “supply chain” had each one query, keywords “digital twin” and “manufacturing” had 41 queries, penultimate keywords “digital twin” and “production” had 27 queries, and at last keywords “digital twin” and “transport” had six queries.

Next two consecutive years had almost the same results. In 2008, keyword “digital twin” had 62 queries as in 2009 it had 67 queries. Keywords “digital twin” and “logistics” had firstly three and in the next year two queries. Keywords “digital twin” and “supply chain” had five queries in both years. Keywords “digital twin” and “manufacturing” had in 2008 47 queries and in 2009 44 queries. Keywords “digital twin” and “production” had firstly 31 queries and in the next year 33 queries. Last keywords, “digital twin” and “transport”, had in 2008 15 queries and in 2009 16 queries.

In 2010, queries had similar results as in previous two years: 66 queries for keyword “digital twin”, six queries for keywords “digital twin” and “logistics”, and also “digital twin” and “supply chain”, 46 queries for keywords “digital twin” and “manufacturing”, 43 queries for keywords “digital twin” and “production”, and lastly, 17 queries for keywords “digital twin” and “transport”.

2011 had slightly higher query numbers for certain keywords: 69 queries for keyword “digital twin”, 11 queries for keywords “digital twin” and “logistics”, eight queries for keywords “digital twin” and “supply chain”, 47 queries for keywords “digital twin” and “manufacturing”, 49 queries for keywords “digital twin” and “production”, and lastly, 15 queries for keywords “digital twin” and “transport”.

Year 2012 is the last year before which queries jumped slightly: 95 queries for keyword “digital twin”, seven queries for keywords “digital twin” and “logistics”, and for keywords “digital twin” and “supply chain”, 58 queries for keywords “digital twin” and “manufacturing”, 53 queries for keywords “digital twin” and “production”, and lastly, 22 queries for keywords “digital twin” and “transport”.

In 2013, queries rose, only to decline in the next year. In 2013, keyword “digital twin” had 105 queries as in 2014 it had 99 queries. Keywords “digital twin” and “logistics” had firstly nine and in the next year six queries. Keywords “digital twin” and “supply chain” had in 2013 14 queries and in 2014 eight. Keywords “digital twin” and “manufacturing” had firstly 61 queries and in the next year 50 queries. Keywords “digital twin” and “production” are the only combination which did not decline in the following year: in 2013 it had 48 queries and in 2014 57 queries. Last keywords, “digital twin” and “transport”, had firstly 30 queries and lastly 21 queries.

Queries grew sharply through the next researched years. In 2015, keyword “digital twin” had 129 queries, keywords “digital twin” and “logistics” had 22 queries, keywords “digital twin” and “supply chain” had 17 queries, keywords “digital twin” and “manufacturing” had 80 queries, penultimate keywords “digital twin” and “production” had 76 queries, and at last keywords “digital twin” and “transport” had 39 queries.

In 2016 there were twice as many or even more queries, not to mention the following year. Firstly, keyword “digital twin” had 296 queries and in the following year 844 queries. Keywords “digital twin” and “logistics” had in 2016 47 queries and in 2017 four times the query

– 195. Keywords “digital twin” and “supply chain” had firstly 61 queries and latter three times the query – 203. Keywords “digital twin” and “manufacturing” had firstly 196 queries and in the next year 573 queries. Keywords “digital twin” and “production” had in 2016 it had 173 queries and in 2014 601 queries. Lastly, keywords “digital twin” and “transport” had firstly 68 queries and lastly 245 queries.

In 2018, keyword “digital twin” had already astonishing 2.430 queries, keywords “digital twin” and “logistics” had 601 queries, keywords “digital twin” and “supply chain” had 535 queries. Keywords “digital twin” and “manufacturing” had enormous 1.560 queries, penultimate keywords “digital twin” and “production” had 1.680 queries, and at last keywords “digital twin” and “transport” had 661 queries.

In the last researched years, the query numbers rocketed. Every combination of keywords had more than thousand queries. In 2019, keyword “digital twin” had 5.610 queries as in 2020 it had 7.780 queries. Keywords “digital twin” and “logistics” had firstly 1.170 and in the next year 1.870 queries. Keywords “digital twin” and “supply chain” had at first 1.100 queries and later 2.070 queries. Keywords “digital twin” and “manufacturing” had in 2019 3.250 queries and in 2020 4.380 queries. Keywords “digital twin” and “production” had firstly 3.300 queries and in the next year 5.170 queries. Lastly, keywords “digital twin” and “transport” had in 2019 1.570 queries and in 2020 2.610 queries.

The significance of the results, in our opinion, will be presented in the next chapter.

5 DISCUSSION

Based on the results above we can state that there is a difference between found articles on the topic of digital twin trend in connection to the field of logistics. Especially between research papers from Web of Science and different contributions from Google Scholar, which cover variety of papers, presentations, articles and other.

5.1 Interpretations of results by Web of Science

Findings based on results from queries on Web of Science show us, that the digital twin trend has appeared for the first time in 2011 and in connection to logistics not until 2017. This can be explained as follows: logistics, as a science, has received a well-deserved awareness and importance (too) late; some companies still do not recognize it as a crucial part of their business environment. There has been a lot of talk about digital twins (not as much writing or even understanding), especially in recent years, but they are also used in various spheres of business, not only in logistics.

Below is a visual representation of the queries of combinations of keywords from Web of Science (Fig. 1). The figure does not show queries before 2010, since the results were zero, as explained earlier.

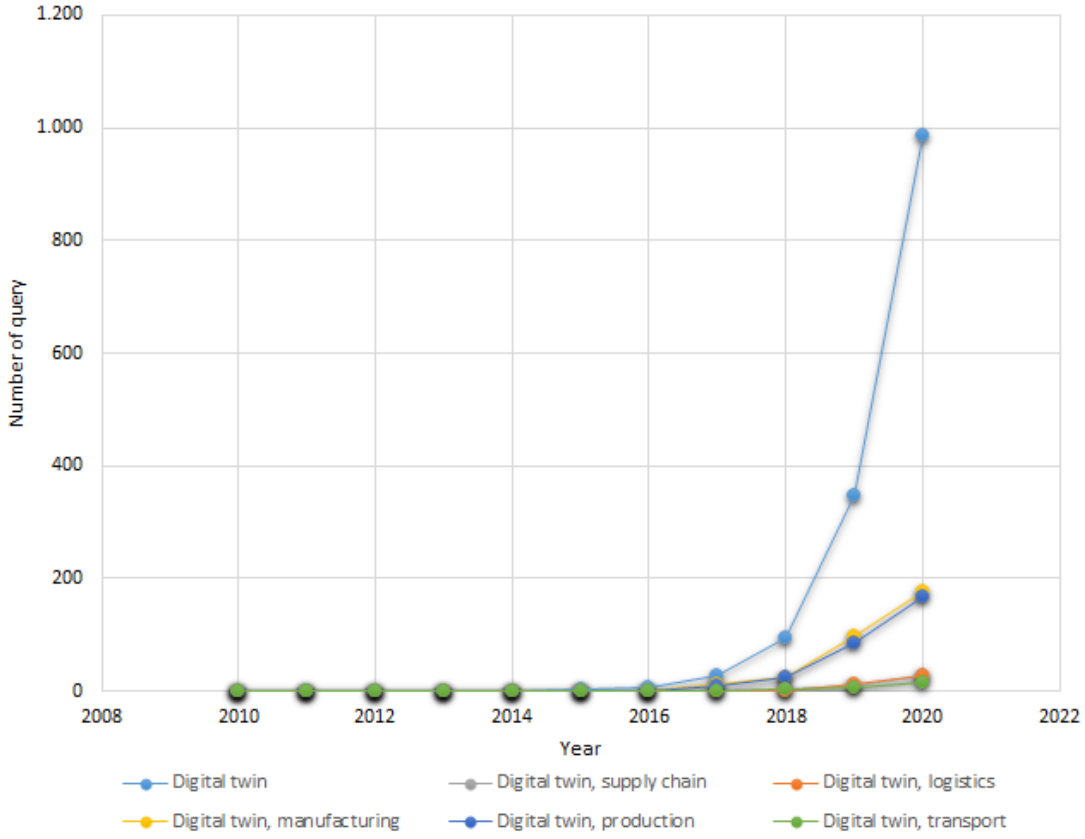

Fig. 1 – Visual representation of query results from Web of Science. Source: own research

We can see (Fig. 1), as far as queries about digital twin independently goes, research papers are rising throughout the years (from 2011 or better say 2013). The remaining queries are also growing, but not at such rate. If we arrange the queries, based on combination of keywords, in descending order, based on the number of results, we get the following:

Digital twin has established its presence in 2011 and is rising significantly.

Digital twin with manufacturing has second most research papers, compared to other keywords query and came to the horizon in 2014 and later in 2017.

Digital twin with production, starting in 2017, is in third place, based on the published research articles.

Digital twin with supply chain appeared in research papers in 2018 and occupies the fourth place.

Digital twin with logistics has risen with research papers only in 2019 and can be put in the penultimate place due to the queries.

Digital twin with transport also appeared in 2018, however, it has a slower growing number of research papers compared with the fourth and fifth-ranked.

5.2 Interpretations of results by Google Scholar

Findings based on results from queries on Google Scholar are different that previous ones – only one of the combinations of keywords did not appear in 2005, but in 2006. As we already stated before, queries from this research include various types of contributions and proceedings, which is why the numbers of results are higher. Below is a visual representation of the queries of combinations of keywords from Google Scholar (Fig. 2).

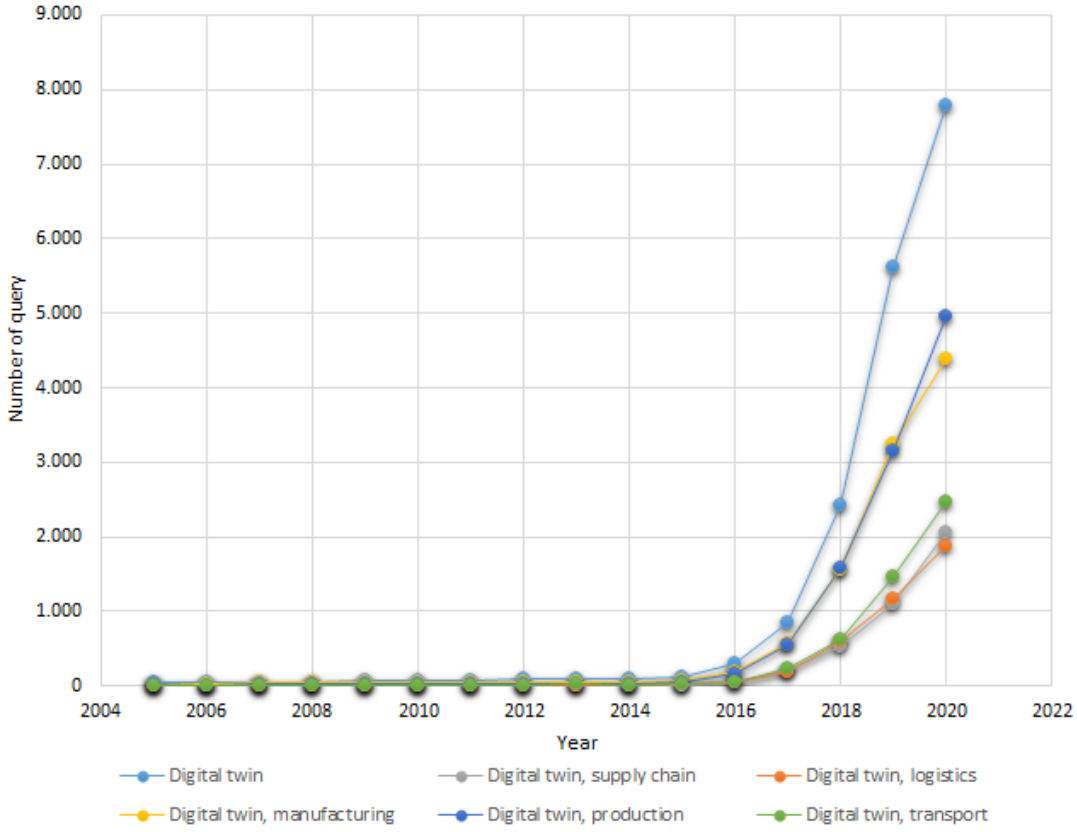

Fig. 2 – Visual representation of query results from Google Scholar. Source: own research

From 2005 to 2015, all queries are at a similar level, as the differences between them are difficult to notice due to the high increase in queries in the final years of the research. As we mentioned before, digital twins were and are used in various spheres of business and fields, that is why we see enormous number of contributions between 2018 and 2020. The growing rate of this keyword is greater than the rest – we again refer to the scope of use of digital twins. As before, we arranged the keywords based on queries, in descending order, and we accumulated the following sequence:

Digital twin has the highest number of queries over the years and far outperforms the rest (with 7.780 queries in 2020).

3.400 queries after the first place (in 2020), we find digital twin with manufacturing, which is the second fastest rising keyword combination.

2.820 queries after the first place and 580 queries before second place (in 2020), we find digital twin with production. Based on the latest year, we could say that this combination should be in second place. But after a closer look, we can determine that the increase of numbers of contributions smaller throughout the researched years.

Digital twin with transport is in fourth place, based on the number of resulting contributions over the years (with 2.480 in 2020).

The penultimate place intertwines with the last. In this position, we have put digital twin with supply chain, based on the sum of all queries over the years (with 2.070 in 2020).

Alas, with slowest growing number of contributions compared with all others is digital twin with logistics (with 1.870 in 2020).

6 CONCLUSION

As far as the publications of articles and contributions on the topic of digital twins is concerned, the greatest leap can be observed in connection with other queries related to logistics and its processes or sub-elements. Which is logical since it is the broadest term and does not allow such a narrowly focused search.

Based on the interpretation of the results we determined, that in both researches – Web of Science and Google Scholar – first three places are reserved for standalone digital twin, followed by digital twin with manufacturing and lastly, digital twin with production. Last three places are scattered randomly between other combinations of keywords. Based on the calculation of the arithmetic mean of the sequences, we can classify importance of the remaining as following: digital twin with supply chain, followed by digital twin with transport, and last digital twin with logistics.

We are aware of the importance of digital twins within production and manufacturing processes, but we find the importance of digital twins within the supply chain and, last but not least, logistics just as or even more important.

For our final conclusion, we can say that there is a lack of scientific contributions on the topic of application and use of digital twins within logistics. We are of the opinion that the number of scientific contributions will continue to increase in the future, but as logistics professionals we would like to place more emphasis on the importance of the trend within the supply chain and logistics.

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FOND MALÝCH PROJEKTOV

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MANAGEMENT CONSULTING IN THE PUBLIC SECTOR OF AN EMERGING ECONOMY: A CASE OF GHANA'S LOCAL GOVERNMENT

Gifty Kenetey, Boris Popesko

Abstract

Despite the numerous studies on management consulting, the fact is that there is little literature and empirical research conducted in regards to the public sector (Local Government). Moreover, the few studies on management consulting have focused on developed nations with little or no attention on developing economies such as Ghana. In the light of this gap, this study sought to explore the views of the staff of selected local government institutions on management consulting in Ghana. The main objective of this study was to know the opinion of public sector workers on the importance, challenges, and impact of management consulting on the public sector. The study drew a sample of 165 through the survey method, and the data were analysed using descriptive statistics and one-way ANOVA. The study found that the public sector's three most common consulting services are organization/Operations management, Project management, and IT consulting. Another finding was that there was no significant between the types of management consulting service and the perception of the importance of management consulting. Further, a weak institutional environment, non-implementation of consultant's advice, and lack of finances were found to be the key challenges faced by the public sector in using management consulting services. The study has implications for management practice.

Keywords: *Management Consulting, Local Government, Public Sector, Emerging Economy, Ghana, Africa*

1 INTRODUCTION

Countries in Asia such as China, South Korea, and India have proved that rapid economic transformation is possible; however, African countries, despite being placed with natural resources than any other continent, have had an unprecedented reduction of poverty over a decade. Modern Africans, however, have seen the need to rise to match up to nations like those in Asia and other developed economies (Mthembu, 2018; Breisinger et al., 2011). Ghana's current reform to take advantage of opportunities available can cause Ghana to catch up with other developed economies soon (Breisinger et al., 2011). Ghana's development is possible through strategic interventions (Annan-Aggrey et al., 2021; Economic Commission for Africa, 2003), and thus the public sector needs to approach management consulting. Since the 1980s, emerging economies have perused public sector reform, which puts pressure on the public sector in emerging economies to embrace private sector management. However, despite effort from nations like Ghana, Ethiopia, Senegal, and Uganda, progress is very little (Nyamori et al., 2017; Economic Commission for Africa, 2003).

The need for public sector reform and economic development has raised the concern for governments worldwide to seek advice from management consultants. Despite many governments' use of management consulting globally, there is little empirical study on management consulting regarding the public sector (Poonsiri, 2017). There are even lower studies on the topic relating to the public sector of Ghana. Even though emerging nations, including Ghana, have embarked on extensive public sector reform agendas, progress remains scant. Progress in emerging economies is hindered by ineffective management practices and

corruption, among others (Kuhlmann & Ordóñez-Matamoros, 2017; Economic Commission for Africa, 2003). Decision-making is characterized by taking a risk; modern-day institutions are faced with the challenge of formulating strategies in a dynamic and fast-growing world in terms of information technology and innovation. Given these, institutions need to hire experts (consultants) to analyse and help bring reform where there is a problem (Vukotić et al., 2017).

The study aims to find out if management consulting is important to the reform of Ghana's Public sector and if consulting firms are contributing positively to the reform of Ghana's public sector. Three objectives are identified for the research, which is to (a) examine the opinion of public sector workers (Public servants) on the importance of management consulting to Ghana's public sector, (b) investigate the challenges of management consulting in the public sector of Ghana and (c) examine the impact of management consulting on the public sector. The following responses to the following research questions provided a solution for the study: (a)What is public sector workers' perception of the importance of management consulting? (b) What challenges does the public sector face in regards to management consulting? (c) What is the perceived impact of management consulting on the public sector of Ghana? Despite the use of management consulting by many governments globally, there is little empirical study on management consulting regarding the public sector (Poonsiri, 2017). The case is even worse relating to the public sector of Ghana base on the literature reviews on the phenomenon. Therefore, this study seeks to bridge this gap.

2 LITERATURE REVIEW

The management consulting profession is tied to policy formulation and implementation concerning the reform of the public sector. Kirkpatrick et al. (2019) defines management consulting as the delivery of strategic advice on how an organization should be operated by analysing and identifying threats, weaknesses, or problems and producing solutions to the issues identified. An attempt to give one definition of management consultancy can attract criticism; researchers have given diverse definitions to management consulting (Jamieson et al., 2016; Sturdy, 2011). Sturdy (2011) reviews management consultancy's definition in dimensions that highlight activities that facilitate organizational change or reform. In addition, aside from the external experts or professionals of the organization, staff within the organization that provides advice or direction to others or the organization can be considered consultants. Another correlate to this broad definition is the type that gives a narrower definition (Curnow & Reuvid, 2005). The authors propose that management consultancy is an exceptional professional service rendered by specially trained and qualified persons.

2.1 Criticisms and challenges of management consulting applicable to the public sector

The increased use of management consulting in public sector organizations has called for many critics and doubts on how efficient it is to reform the public sector and projects delivery (Shaw, 2021; Howlett & Migone, 2013). Some of their opinions have been substantiated with shreds of evidence of failed public sector consultancy with examples like the case of the US's Ricker Island Prison and the UK's National Health Service. Some Strategic observation contributes that the reason is that consultancy is designed to produce symbolic solutions to their client's problems and thus seen as expert image whiles another view argues that consultants are limited to their client's demand. Thus, the problem lies with the client who fails to maximize the usage of the consultant (Poonsiri, 2017; Brint, 1990: Howlett & Migone, 2013; Dias Simões, 2018). Brint (1990) gave variables that affect the consultant's ability as follows: (a) Technocracy: this explains where the consultant has much influence on policymaking as Government subject action becomes technical and complex; (b) Servant power: The consultant exists as a 'servant' of the Powerful that provides a 'window dressing; (c) Limited mandate: this talks of the

consultant as a mediator, whereby the consultant can overrule or dominate policymaking but only in particular cases that require technical knowledge; and (d) Extensive mandate: this is similar to the technocracy; however, the expert perceived influence is on just a specific area of policymaking.

The study of Brint (1990) suggests that the consultant is a 'Servant of Power' and thus has a limited mandate rather than being a technocratic elite with influence. Brint (1990) suggests some level of 'autonomy' to be offered to the consultant within his work area. Although the work of a consultant is not subject to public scrutiny, Governments should set aside public bodies that audit and appraise the consultant's performance. This view, however, does not represent a general view of management consulting but base on a few researches.

Although management consultancy brings innovation and organizational effectiveness, Hoecht and Trott (2006), Effah and Adam (2021) and Back et al. (2014) argue that the instance may not always be positive. Back et al. (2014) argued that innovation outsourcing, as in the case of consultancy, has challenges of information leakage. The view is that over-dependence on outsourcing or management consultancy can erode internal capabilities that organizations need to concede and exploit their ideas or new opportunities.

2.2 Importance of management consulting

Sturdy (2011) opines that consultancy forms an integral part of management and its distinctive roles placed in its structural position, and it is ambiguous, visible and accountable than its occupational, professional identity claims. Kirkpatrick et al. (2019) Also express the significant roles management consultants have played in formulating and implementing policies focused on public management reform. The authors further outlined that England hired consulting firms like Mckinsey to reconstruct the bank of England, including other public bodies like the British Railways, in 1968. Consultants have played vital roles in the reform of the English National Health Services (NHS), this to some observers, created an industry for consultants (Alderwick et al., 2016).

2.3 Perceptions of public servants on management consulting

The behaviour of organizations is influenced by their socially constructed reality (Crișan & Stanca, 2021); meanwhile, public sector organizations are also structured by management consultancy (Kirkpatrick et al., 2019). The authors opine that public organizations perceive management consultants for exploitations that boost their services by manipulating policymakers to make money; thus, they are not likely to add value. The authors argue that these perceptions of the public sector do not have any robust empirical evidence support. However, the reason for such perception is tied to the fact that there is unavailable data for benchmarking the services of consulting against outcomes. Crișan and Stanca (2021) also revealed that what hinders the assessment of management consulting in the public sector is a result of the political sensitivity associated with public project consultancy in many countries. The authors explain that both the public organization and the management consultant are primarily unwilling to disclose information for formal evaluation due to political sensitivity.

3 METHODOLOGY

Data was collected from the public sector of Ghana; the public sector of Ghana consists of several public institutions (service and non-service organizations). Due to the large population in the public sector of Ghana, the study concentrated on responses from the local government sub-sector per the research aim. In doing so, a non-probability sampling technique was adopted to collect data, precisely the purposive sampling technique. The rationale behind selecting this

method is to ascertain the qualified subjects capable of fulfilling the research objective. In other words, the research relied on MMDA's staff (Metropolitan, Municipal, and District Assemblies) under the Local Government. These are agencies and departments in which this research is considered as the sampling units of the study.

Considering the nature and the purpose of these agencies and departments, it was time/cost-effective when implementing the purposive sampling method; see (Taherdoost, 2016). Considering the dispersed nature of the MMDAs and the fact that the data collection period coincided with the COVID period, it was difficult accessing a large sample. Thus the 180-sample size was deemed appropriate under the circumstance. To validate the research instrument, the study pretested the questionnaire by administering it to 10 participants who were experts, directors, and department heads in the local governance system. Suggestions and comments gathered through the pre-test were incorporated to produce the final questionnaire.

Due to the presence of the Covid 19 pandemic, the researchers relied on electronic transmission of responses; that is, only soft copies of the questionnaire through google docs link were sent to the target respondent through emails, Facebook messenger, and WhatsApp platform. It is essential to state that only staff of these mentioned MMDAs took part in the survey. Given the total population size of 254 MMDAs in Ghana, which are widely scatted across the sixteen (16) regions in Ghana, the study focused on staffs of MMDAs from four geographical locations, i.e., Accra Metropolitan Assembly, Ga east Municipal, Ho west District, and WA east district Assembly. Out of the 170 responses retrieved, 165 were valid for this study representing a 97% response rate. Fifteen (15) research questions were designed for the survey: comprising respondent profile in the first part and the main research variables in the second part

The data collection took three months, from March to June 2020.

4 RESULTS

This section presents the results of the study, which are primarily in the form of tables. For instance, Table 1 presents the findings on the types of management consulting services that the Local Government often engages in. Question one of this study sought to know the opinion of public sector workers regarding the importance of management consulting. To address this question, the respondents (MMDAs) were presented with seven Management consulting service lines and asked to indicate which consulting services their organizations subscribe to. The responses are presented in the Tab. 1.

Tab. 1 – Types of management consulting service. Source: own research

Consulting services	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Min	Max
					Lower Bound	Upper Bound		
Strategy	6	6.2	0.4	1.6	5.7	6.6	6	7
Organization/ Operations Management	61	5.6	1.1	0.1	5.3	5.8	3	8
Project Management	21	5.4	1.3	0.3	4.7	6.0	3	8
Change Management	6	6.3	0.5	0.2	5.8	6.9	6	7
HR Consulting	10	5.7	1.2	0.3	4.9	6.5	4	7
IT Consulting	54	6.0	0.9	0.1	5.8	6.3	3	8
Finance Accounting	7	4.3	2.3	1.3	-1.4	10.1	3	7
Total	165	5.7	1.1	0.1	5.6	5.9	3	8

As shown in Tab. 1, 61(37%) of the public organization engages organization/operations management consulting service, and 54 (33%) of the respondents reported IT consulting as their

management consulting service line. Additionally, 21(13%) of the public organizations reported project management as the consulting service line they engage, while 10 (6%) of the respondents engage in HR consulting. Strategy, change management, and financial accounting recorded 6 (3%), 6 (3%), and 7 (4%) respectively as the service lines engaged by the public sector.

To know the perception of the respondents on the importance of management consulting, a one-way ANOVA was run. In running the ANOVA, the types of management consulting services were used as the independent variable and the importance of management consulting as the dependent variable. Table 2 below shows the results of the ANOVA.

Tab. 2 – ANOVA results on perception on the importance of management consulting. Source: own research

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	18.6	6	3.109	2.647	.018
Within Groups	180.8	154	1.174		
Total	199.5	160			

Correlation is significant at the 0.01 level (2-tailed).

As Tab. 2 depicts, the relationship between independent and dependent variable was not significant, i.e. $F(6,154) = 2.647$, $p=0.018$. Since $p>0.01$, there is no significant between the types of management consulting service and the perception of the importance of management consulting.

To answer the second research question, the study sought to know the challenges faced by the public sector relating to management consulting, and the respondents were presented with four key challenges for them to indicate the ones that they face. Table 3 shows the results of the respondents' choices on these challenges.

Tab. 3 – Challenges faced by public sector on management consulting. Source: own research

Challenges	Frequency	Percent (%)
Weak institutional environment	90	55
Financial challenge	28	17
Non-implementation of consultant advice	43	26
Perceived incompetence of consulting firms	4	2
Total	165	100

As shown in Tab. 3, the challenge of a weak institutional environment recoded 90 responses representing 55%. Financial challenge recorded 28 respondents, which forms 17%, while non-implementation of consultant's advice recorded 43 respondents forming 26%. Perceived incompetence of consulting firms recorded four respondents representing 2%. Therefore, the three critical challenges faced by the public sector in using management consulting services are a weak institutional environment, non-implementation of consultant's advice, and financial challenges.

To answer the third research question, the respondents were asked to indicate the impact management consulting services have on the public sector. The result is presented in Table 4.

Tab. 4 – Impact of management consulting on public sector. Source: own research

Impact	Frequency	Percent (%)
Solutions to mitigate management risk/challenges	105	64
Arbitration services	22	13
Timely expert advice	28	17
Professional knowledge and skills	7	4
Objective advice	3	2
Total	165	100

The results presented in Tab. 4 provide an in-depth understanding of how management consulting impacts the public sector. Looking at the results, 105% of the public servants agreed that management consulting influences the public sector by finding solutions that mitigate risk/challenges. Additionally, 28 (17%) of the public servants also agreed that management consultants provide timely expert advice. Whiles 22 (13%) of them agreed that management consultants act as arbitrators between public institutions and other parties, seven (7) respondents representing 4% also agreed that management consultants' impact on professional knowledge. Lastly, 3 (2%) of them indicate that management consultants provide objective advice. From this analysis, it is seen that management consulting has an impact on public sector institutions.

5 DISCUSSION

The study sought to find the perception of the public sector regarding the importance and impact of management consulting, including the challenges they face. The study found that the public sector's three most commonly consulting services are Organization/Operations Management, Project management, and IT consulting. Furthermore, the study sought to find the relationship between these commonly used consulting services and how the public service perceived them as important. Contrary to expectation, the analysis shows that there was no significant difference between how the public servants see management consulting service as important. Based on the analysis, the public servants' key challenges are a weak institutional environment, non-implementation of consultant advice, and financial challenges.

This finding lends credence to the study of previous studies (Senyo et al., 2021; UNESCO, 2010; Back et al., 2014) regarding the issue of weak institutional void and the challenges faced by the target population relating to the objective for this study. Senyo et al. (2021) and Back et al. (2014) found that weak institutional void is a challenge in emerging economies, whiles UNESCO (2010) presented that information technology is identified by the techno-economic paradigm in developing or emerging economies; however, innovation, including research and development is complicated and incomplete. This finding can be traced to why the public sector organization highly rated IT consulting as IT-related services are now gaining ground in emerging economies, especially African economies. Thus, there is a higher growth rate for IT consulting in public service in Ghana.

Additionally, results on the financial challenge could be aligned with a previous study that management consultants charge high fees and that their advice is not statistically related to efficiency (Kirkpatrick et al., 2019). Chugunov et al. (2019) also argue that public finance instruments for reforms in emerging economies are mostly borrowed from developed economies, pointing to the fact that emerging economies are faced with financial challenges.

The third finding shows that most of the public sector agreed that management consulting impacts the public sector by providing solutions that mitigate management risk/challenges. This also points to the fact that management consulting is helpful in addressing challenges.

5.1 Theoretical contributions

There is very little research on management consulting relating to local governance in the public sector, especially in emerging economies. The present study presents the significance of management consulting to emerging economies and contributes to the ongoing debate on management consulting in governance, and strengthens the theoretical assumptions on the ideas of management consulting, which suggest solutions to complex organizational processes. The findings of the study also present strength for an understanding of management consulting in governance to practitioners and scholars seeking to develop ideas for future research

6 CONCLUSION

The study established the field that consulting is most needed in the local government service of Ghana and has also drawn attention to the key challenges that affect the efficiency of management consulting within the scope of the study. It is also established that management consulting offers a positive impact to MMDAs base on their response. Although the study makes a significant contribution, it also has limitations. The data set was drawn from only four MMDAs due to the COVID 19 pandemic during the time of data collection; therefore, generalizing the findings will be problematic. Given this limitation, the study recommends that future studies consider gathering data that best represent the entire public sector.

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INTERREG V-A SLOVENSKÁ REPUBLIKA ČESKÁ REPUBLIKA SK-CZ 14-20

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FOND MALÝCH PROJEKTOV

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CONTRIBUTION ASSESSMENT AND STAFF COMPENSATION AS A WAY TO MANAGE KNOWLEDGE

Natalia Khazieva, Dagmar Cagáňová

Abstract

Knowledge and knowledge management are the fundamental basis of any organization operating in a knowledge-based economy. The questions of knowledge performance have been broadly discussed over the past 25 years from different viewpoints: creation, acquisition, transfer/sharing, usage, loss, etc. Herewith, the knowledge process and knowledge management initiatives often face failures. To inspire the ongoing development of knowledge, companies are developing various incentive programs. Usually, rewards act as a tool to encourage knowledge expansion among organizations. The originality of this paper lies in an updated methodology of estimating staff compensation for contributing to knowledge creation, acquisition, and avoidance of knowledge loss. The main outcome of this work is a model that will be used for further research in promoting staff compensation for knowledge development. This method can be seen as a supplement to the main remuneration system, as all initiatives and knowledge management processes are often performed as additional work and are not the main responsibility of the employee.

Keywords: *reward system, knowledge dynamics, estimation of knowledge contribution*

1 INTRODUCTION

Knowledge represents a critical resource in companies, because it is a focal point of competitive advantage in the knowledge-based view of a firm. The main processes of knowledge dynamics are the following: knowledge creation, knowledge acquisition, knowledge loss, knowledge sharing, knowledge storage and retrieval, knowledge diffusion, conversion from one form of knowledge into another, and organizational learning. Scholars and researchers often concentrate on one process, paying substantial amount of attention to knowledge creation and usage. At the same time, the amount of lost knowledge may be significant and different strategies need to be implemented to avoid such knowledge loss. Knowledge could be lost in both internal and external environments through employees leaving their jobs, retirement of employees, and knowledge management failures.

The purpose of this paper is to propose a model for estimation of the employee's compensation based on the contribution in knowledge development. In order to achieve this goal, the authors of the paper have studied various models describing the essence and functioning of knowledge, and have updated the model provided by Charnes et al. (1955). The decision over this model's choice was based on the fact that it may be applied to evaluate the contribution of employees in knowledge sharing, knowledge acquisition and avoidance of knowledge loss, as the organization can determine what types of employee behaviour contributes to the development and management of knowledge.

The structure of the paper is as follows: Section 2 briefly describes the main models of knowledge dynamics. Section 3 presents the model of staff compensation based on the contribution to knowledge development. Section 4 and 5 explore the application of this model and its main limitations, and the last section summarizes the results.

2 KNOWLEDGE DYNAMICS MODELS

The main debates on knowledge lie on the deference between knowledge as a noun (meaning object such as documents and other "repositories") and knowing as a verb (meaning interpretation, process and relationship) (Mitchell & Boyle, 2010). According to this difference, different research proposed dynamics models.

The most well-known work about knowledge dynamics is the one of Nonaka and Takeuchi (1995). The authors described the meaning of knowledge using several terms: explicit knowledge, tacit knowledge, and social context (Ba). Explicit knowledge is knowledge that can be expressed, codified, stored and accessed. It can be easily transmitted using verbal and written communication. Tacit knowledge is more complicated: "Tacit knowledge is highly personal and hard to formalize, making it difficult to communicate or to share with others. Subjective insights, intuitions, and hunches fall into this category of knowledge. Furthermore, tacit knowledge is deeply rooted in individual actions and experiences, as well as in their ideals, values, or emotions he or she embraces" (Nonaka & Takeuchi, p.8). Explicit and tacit knowledge interact past the special setting or Ba (meaning conditions). During this process of interaction, knowledge is shared, created and utilized. Ba is not only a physical space, but also a "multilevel interactive state that explains the interactions that occur at specific time-space" (Nonaka et al., 2008, p.34). Knowledge obtained by a person can be shared, re-created, and improved, only when he or she actively performs in Ba.

Later, this model was developed by the idea of knowledge being a process (Nonaka et al., 2008). This means that knowledge continuously transforms through four basic processes: socialization (tacit to tacit), externalization (tacit to explicit), combination (explicit to explicit), and internalization (explicit to tacit) – SECI model.

Socialization is the process of transferring tacit knowledge by creating a physical or virtual space, where a certain community may exercise social interaction. Externalization is the process of articulation of tacit knowledge into explicit knowledge and assumes knowledge creation and sharing. Combination is the process of integrating concepts into a knowledge system (Yeh et al., 2011). Internalization is the process of structuring the explicit knowledge as tacit knowledge. Internalization is very close to learning-by-doing. The whole knowledge creation process runs in a spiral. In a simplistic way, the model is illustrated in Figure 1.

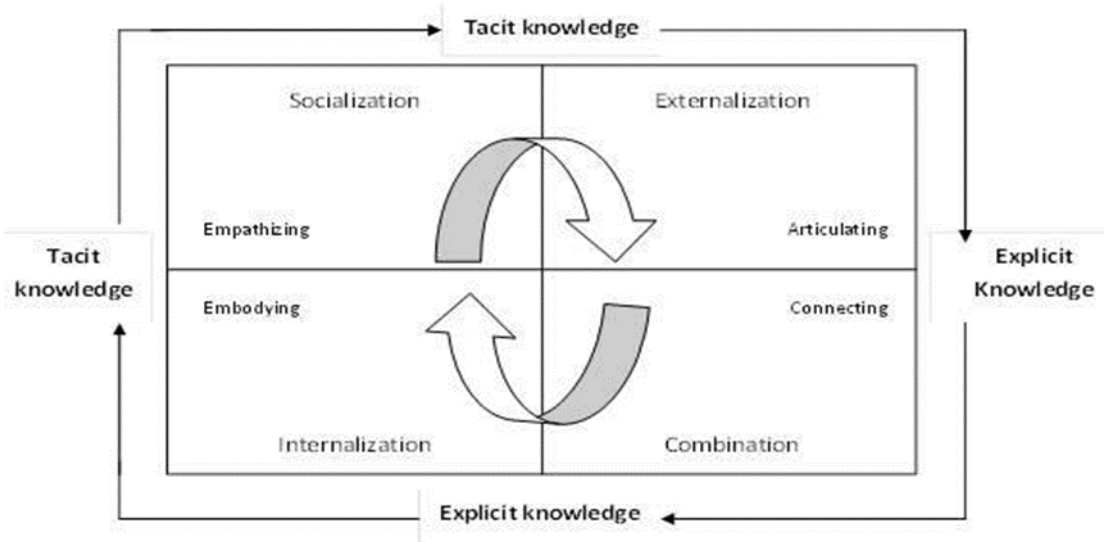

Fig. 1 – The SECI model. Source: Nonaka & Takeuchi (1995)

The main points of criticism of Nonaka and Takeuchi's model are related to the absence of categories of time and place. Furthermore, the model does not explain how new ideas and solutions are developed in practice (Bereiter, 2002).

In 2006, Nissen expanded Nonaka and Takeuchi's model. The scholar added time as an independent fourth dimension (see Figure 2). He suggested two new ideas: life cycle and knowledge flow. "Life cycle refers to the kind of activity (e.g., creation, sharing, application) associated with knowledge flow. Flow time pertains to the length of time (e.g. minutes, days, years) required for knowledge to move from one person, organization, place, or time to another" (Nissen, 2006, p. 35).

The life cycle includes the following steps: creation, organization, formalization, sharing and application. The flow time dimension is described by using different types of arrows: the thin arrow representing fast flow, the thick arrow representing slow flow.

The main critics of Nissen's model are connected to the absence of a metric to measure the speed of flow or its acceleration.

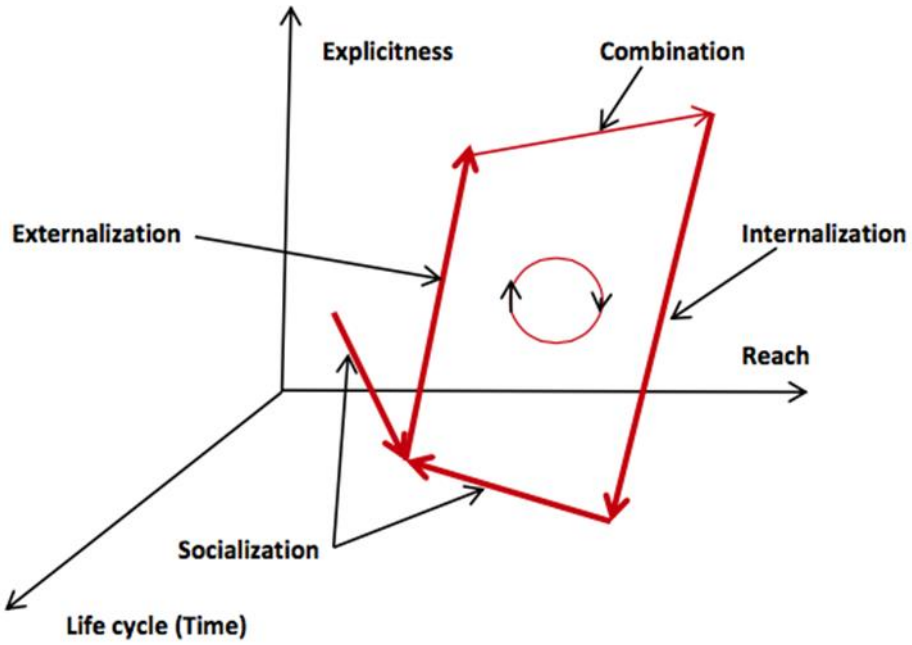

Fig. 2 – The Nissen's knowledge dynamics model. Source: Nissen (2006)

Later, Bratianu et al. (2011b) proposed the Organizational Knowledge Dynamics (OKD) model (see Figure 3). The OKD model shows that knowledge creation adds new knowledge to the already existing; knowledge sharing changes the distribution of knowledge within an organization but does not add new knowledge; knowledge acquisition that introduces new knowledge in an organization; and knowledge loss which decreases the organizational knowledge. Knowledge could be lost inside and outside the organization. Knowledge loss within the internal environment happens through unlearning and forgetting (this last component is not shown in Figure 3).

Since knowledge is created, acquired, shared and lost by humans, people may also manage it within the organization by establishing the proper environment and by influencing employees in order to achieve the equilibrium equation. A proper environment includes all - physical space, necessary tools and infrastructure, and social context. By providing space, supplying resources and establishing communities, the organization provides an opportunity to create, acquire, share and even lose knowledge, but it may also stimulate employees to do or not to do this.

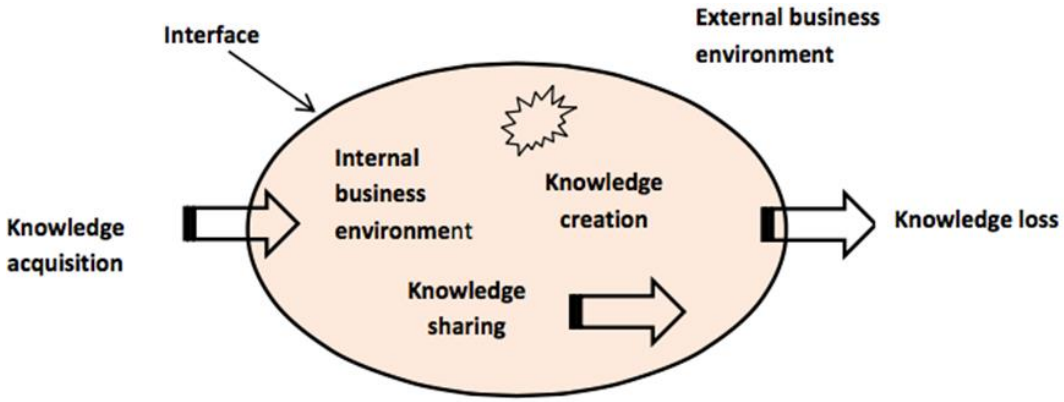

Fig. 3 – The Organizational Knowledge Dynamics (OKD) model. Source: Bratianu et al. (2011a)

The issue of how to stimulate knowledge creation, knowledge acquisition, knowledge sharing and avoid knowledge loss is broadly discussed in literature. However, majority of this attention is paid to stimulating the workers to share or transfer their knowledge to others. Thus, Lin and Joe (2007) explained the motivation behind sharing and not sharing knowledge with others. Tohidinia and Mosakhani (2010) emphasized the key factors that influence knowledge sharing. However, Sajeva (2014) concluded, after a literature review, that there is no common opinion about the positive influence of a reward system on knowledge sharing, even despite some authors finding significant relationships between reward systems and knowledge sharing within organizations (Al-Alawi et al., 2007; Alam et al., 2009; Jahani et al., 2013). Others have also investigated this, and concluded that rewards do not influence employee behaviour and their plans to share knowledge to any considerable degree (Olatokun & Nwafor, 2011; Seba et al., 2012). Even more importantly, there is no final confirmation of the role of reward (Zhang et al., 2010).

If the organization does not motivate and stimulate the creation of new knowledge, acquisition of knowledge, and does not prevent knowledge loss, a conflict of interest will occur. Gal and Hadas (2015) explain this the best: "After a trial-and-error period, the knowledge worker finds that if he/she stays within the maximum good level or the minimum bad level of performance, no one will notice the difference. The knowledge worker is not going to be appreciated for extra efforts or be punished for lower work quality. This situation may encourage a knowledge worker to perform at a lower work quality level. Economically, it is very logical. Because the knowledge worker receives the average reward of the reference group, delivering lower quality creates an immediate short-term benefit for the worker. The knowledge worker puts less effort into their work for the rewards he/she has received <…>" (p. 971). Therefore, an assessment of the employee's contribution to knowledge creation, knowledge acquisition and avoidance of knowledge loss should take place. In organizations, rewards are studied as motivators, because they determine how employees respond to certain stimuli (Martin-Perez and Martin-Cruz 2015). Establishing agreements between employee and employer that include additional rewards for achieving the desired results and punishments for poor performance that do not lead to the organization's goals is a solution to take staffing out of the employees' control of knowledge and manage this process.

3 METHODOLOGY OF ESTIMATION STAFF COMPENSATION

Certain mathematical tools, such as exact methods of solving problems of human resource management, have limitations in their application. This is explained by the fact that when solving problems of this kind, one has to take into account a significant number of factors of different degrees of importance, arising from the mutual requirements of the team, individuals,

and the organization, toward each other (Moder & Elmaghraby, 1978). However, some mathematical tools can be applied to the following functions, which act as the foundation of control: (1) Staffing of the organization; (2) Professional development of employees; (3) Use of labour resources; (4) Assessment of personnel efficiency; (5) Reward system and motivation of employees.

Often, the implementers and leaders of knowledge management initiatives combine the responsibilities and tasks of implementing them with their main job. Still, exact methods are used mainly to determine monetary compensation for the work performed.

In general, the problem of payment and reward can be formulated as

$$S = f\ (\mathrm{A}, \mathrm{O}, \mathrm{E}) \tag{1}$$

where

S – salary,

A are indicators characterizing performers (for example, productivity, profession, age, work experience, education, etc.);

O - variables characterizing the organization in terms of the overall level of remuneration for comparable jobs, the structure of remuneration in accordance with the positions, the dependence of remuneration on the hierarchy of positions, the needs of the organization in certain professions, the total level of income, etc.;

E - external variables, such as labour legislation, hiring rules, the influence of trade unions, etc.

It should be noted that with such a formulation of the problem of payment and reward, pay is a function of income, and the sets O and E are constraints, not variables.

Charnes et al. (1955) proposed a different formulation of the problem of payment and reward:

$$s = \sum_{i=1}^{n} a_i y_i \tag{2}$$

where

S – salary,

a_i – weight to be assigned to i^{th} factor;

y_i – amount of factor *i* possessed by a person whose salary is to be determined.

Let:

x_{ik} be the known amount of factor *i* (as rated) which is necessary for job level *k = 1, 2, …, L.*

The jobs be ranked according to the descending order, *1, 2, …, L*, so that the subscript shows the position of the job in the hierarchy. The salaries connected with these jobs are in the same descending order.

There is a salary ceiling, s_M and a salary floor, s_m, established in advance. If intermediate level (s^i) is known, it may be also used.

$a_i \geq 0$ on the weights is introduced.

Scholars articulated several requirements: (1) Yield a linear formula. (2) Respect the ranked position-hierarchy of the company (an employee at a lower position must not receive more

compensation than the president). (3) Provide competitive conditions to avoid losing valuable employees to competitors. (4) Avoid negative weights for any factor. (5) Avoid bias on the company's current salaries.

Then, a series of inequalities are received:

$$\sum_{i=1}^{n} a_i x_{i1} \leq s_M \tag{3}$$

$$\sum_{i=1}^{n} a_i x_{i2} \leq \sum_{i=1}^{n} a_i x_{i1} \tag{4}$$

$$\sum_{i=1}^{n} a_i x_{iL} \leq \sum_{i=1}^{n} a_i x_{i(L-1)} \tag{5}$$

$$s_m \leq \sum_{i=1}^{n} a_i x_{iL} \tag{6}$$

$$a_i \geq 0 \tag{7}$$

where the "level" requirements are given by, s_M and s_m.

4 RESULTS AND DISCUSSION

Charnes et al. (1955) proposed a model for estimating the executive compensation in an industrial organization. However, this method could also be applied to evaluate the contribution of employees in knowledge sharing, knowledge acquisition and avoidance of knowledge loss, because organizations can determine what types of employee behaviour will contribute to the development and management of knowledge. Additionally, the organization may differ in the degree of influence and designated employee's behaviour that should be encouraged.

Table 1 presents the ranked data of behaviour types. Under the column R, the position rankings of the job (and their representatives) are listed from high to low: R_1, R_2, …, R_7. In the columns titled P_1, P_2, …, P_7, factors of employees' behaviour connected with knowledge sharing, knowledge acquisition and avoidance of knowledge loss are listed and associated with ranked positions. Factors of behaviour are subject to change and depend on organizational goals and strategy. The listed factors are just an example of possible aspects of estimation. They may change over time based on what behaviour among employees the company desires to support and stimulate. These are the x_{ik}, k = 1, 2, …, L of the inequations (3), L = 7. Meaning, the employees who possess the position R_1 receive a rating $x_{11} = 4$ under P_1, Openness with others; and a rating $x_{12} = 5$ under P_2, Acceptance of responsibility.

x_{ik} could be obtained from a salary survey conducted by the HR department. In such a survey, not only employees participating in the knowledge management initiatives in the company, but also the involvement of their managers, colleagues, companies' customers or suppliers will facilitate a more wholesome assessment of the employee's contribution from different sides. The frequency of such a survey depends on the company's goals. These surveys can occur monthly, upon completion of the knowledge management initiative, upon completion of the fiscal year in order to calculate the annual bonus, etc.

Tab. 1 – Position Ratings associated with Types of Behaviour. Source: own research

Position R	Openness with others P_1	Acceptance of responsibility P_2	Learning ability P_3	Initiative P_4	Planning Ability P_5	Experience P_6	Ability to finish tasks P_7
R_1	4	4	4	4	5	4	4
R_2	3	4	3	4	3	4	4
R_3	3	2	3	2	3	2	2
R_4	1	3	2	4	3	2	3
R_5	0	2	2	1	1	4	2
R_6	0	2	2	2	1	1	1
R_7	2	3	3	2	1	1	0

The company must also determine the "cost" of each factor (P_1, P_2, …, P_7), meaning how highly it appreciates the manifestation of one or another behaviour. Here, it is important not to overestimate or underestimate. In this instance, it is possible to turn to the services of consultants to implement knowledge management, take some percentage of the average of all salaries involved in the implementation of employee knowledge management, and the average cost of training intended for the development of skills (types of behaviour).

Table 2 presents the possible estimation of each factor P_1, P_2, …, P_7. The provided data is presented as an example and is not the basis for assessment for future research and estimation in other organizations.

Tab. 2 – The possible estimation of factors P_1, P_2, …, P_7. Source: own research

Factor/ type of behaviour	Openness with others P_1	Acceptance of responsibility P_2	Learning ability P_3	Initiative P_4	Planning Ability P_5	Experience P_6	Ability to finish tasks P_7
"Price"	1200	1250	1300	1350	1400	1450	1500

By filling out the specified table and making calculations according to the proposed method, the organization can get different compensation values for different employees. Using the Simplex Method, we may discover the level of salary (see Table 3).

Tab. 3 – The results of estimation of salary. Source: own research

Position R	Openness with others P_1	Acceptance of responsibility P_2	Learning ability P_3	Initiative P_4	Planning Ability P_5	Experience P_6	Ability to finish tasks P_7	Salary S	Limitation
R_1	4	4	4	4	5	4	4	180	≤ 66150
R_2	3	4	3	4	3	4	4	180	≤ 66150
R_3	3	2	3	2	3	2	2	90	≤ 66150
R_4	1	3	2	4	3	2	3	108	≤ 66150
R_5	0	2	2	1	1	4	2	144	≤ 66150
R_6	0	2	2	2	1	1	1	45	≤ 66150
R_7	2	3	3	2	1	1	0	135	≤ 66150

The main limitation is associated with obtaining the estimates of factors (P_1, P_2, …, P_7). Who should assess the level of factor implementation? Among the possible options are: the manager, colleagues, the HR department and the employee himself /herself, through a plan-fact analysis. This issue requires additional study because it may be subjective.

Despite the limitations, this method may be used to estimate the contribution of employees involved in the implementation of new knowledge management initiatives in any department. This method may be considered as a supplementary way to the main reward system, because often, all initiatives and processes of knowledge management occur as additional work and are not the main responsibility of workers.

5 CONCLUSION

The purpose of this paper is to propose a model to estimate employee compensation based on the contribution to knowledge development. To achieve this purpose, first of all, the authors of the paper have exploited existing knowledge dynamics concepts, their elements and limitations.

Since knowledge is created, acquired, shared and lost by humans, people may also manage it within the organization by establishing the proper environment and by influencing employees in order to achieve the equilibrium equation. The reward system represents the main incentive of worker performance. It is very difficult to choose a model that would take into account both the employee's contribution to the development of knowledge and establish the appropriate compensation for such actions. Moreover, over time, the priorities of an organization may shift and other types of behaviour must be encouraged. The compensation assessment model should take these factors into account accordingly. The originality of this paper is underlined by the fact that the authors have proposed the use of Charnes, A. et al. (1955) model with a change in the evaluated factors, linking them with the influence on the creation of knowledge, knowledge acquisition and avoidance of its loss.

This method can be seen as an additional way to the main remuneration system, as all initiatives and knowledge management processes are often performed as additional work and are not the main responsibility of employees. This model is a useful quantitative tool to evaluate the contribution of employees to the development of knowledge.

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HOW INTEREST RATES SHAPE REMITTANCE BEHAVIOUR OF IMMIGRANT WORKERS IN THAILAND: A THEORETICAL FRAMEWORK

Virak Khiev

Abstract

Little is known about the theoretical aspect of immigrants' remittance behaviour in response to interest rate policies of the host country Thailand. This article aims to examine how the interest rate policies of Thailand shape remittance behaviour of immigrant workers by using the two-period remittance-saving model. According to the model, a migrant decides how much to remit and save while holding consumption constant. The results are that (i) the increase in interest rate reduce remittance flows in the current period, while the flows in the future period are ambiguous for the case of borrowing (legal) migrants; (ii) for the saving migrants, the rise in interest rate in the current period increase remittance flows in the future, while the current remittance flows are unclear; (iii) remittances sent by illegal migrants are expected to be free from interest rate policies. The limitation of the framework is that it fails to incorporate factors in the home countries, such as interest rates and incomes of remittance recipients.

Keywords: *Interest rate policies, remittance flows, Two-period framework, Intertemporal Budget Constraint, Indifferent Curve*

1 INTRODUCTION

Thailand has been the main destination for both documented and undocumented migrant workers from its neighbouring (CLM) countries Cambodia, Laos, and Myanmar, and some migrant workers from Vietnam. The stock of immigrant workers in Thailand was estimated to reach 3.9 million in November 2018 (Harkins, 2019), accounting for 10% of the total workforce. Myanmar stood on the top with the highest number of migrant workers, followed by Cambodia and Laos. Collectively, these migrant workers send USD 2.8 billion in formal or regulated remittances per annum to their countries of origin, although the figures should increase to USD 8-12 billion if they manage to transition from informal to formal use of remittance products (Harkins, 2019). Hence, these substantial flows of remittances constitute crucial sources of income for households in their home countries.

In the host country Thailand, the macroeconomic role of immigrants' remittances is further emphasized by its responsiveness to macroeconomic policies. Theoretically, some macroeconomic variables in the host county should affect remittance flows. For example, an interest rate cut in the host country is expected to increase the outflows of remittances. Recall that monetary policy tools, particularly interest rates, were used to tackle the economic crises caused by the global financial crisis (GFC) in 2008-2009, the 2011 Japanese earthquake and the 2011 Thai floods. The empirical evidence showed that countercyclical interest rate cuts consistent with the inflation target increased the resilience of the economy to these shocks (Alp & Elekdag, 2012). These interest rate policies pursued by the central bank of Thailand were quite likely to affect the allocation of financial resources of local households, businesses, and immigrant workers. The discussion on the efficacy of the interest rate policies perhaps focused on the first two economic entities thereby overlooking the policy's effect on remittance behaviour of immigrant workers.

In the literature, little is known about the remittance behaviour of immigrant workers in Thailand. Hence this article aims to analyse the effect of interest rates in the host country Thailand on remittance behaviour of immigrants by using the two-period remittance-saving model. This analysis will provide additional knowledge to readers who wish to know about remittance behaviour of immigrants in a middle-income country, especially a country with a relatively high number of illegal immigrants. The organization of the study is as follows: first, a short review of empirical studies will be given, followed by a general framework. The next part will analyse the link between remittances and interest rates by using indifference curves. Finally, the study will be concluded with a summary of the results and limitations of the framework.

2 LITERATURE REVIEW

At the individual level, the most prominent explanation of remittance flows is owned to the study of Lucas and Stark (1985). According to the study, several motives affect remittance flows. Of them, altruism and investment, which is a subset of pure self-interest, are perhaps the most important motives. Mannan (2017) found that altruism and investment are the main motives behind remittance flows to Bangladesh. Other studies show mild support for altruistic motives (Jena, 2016) and insignificant for the entire sample from Indian migrant workers (Antoniades et al., 2018). But when using the propensity to share with others as a proxy for altruistic motives and its interaction with loan obligation, Antoniades et al. (2018) found a strong positive relationship between altruism and remittances for a subset of a sample with a loan obligation. In addition to these economic motives, social structure of immigrant workers in the host and home countries are also expected to shape their remitting behaviours. Aparicio Fenoll and Kuehn (2018) showed that immigrants remit more if they live in larger networks. Also, migrants in larger networks are less likely to use the most expensive remittance channels. And the cost spreads between the most expensive and cheapest remittance service provider are lower for countries characterized by stronger networks. Similar results were shown by Mannan (2017) – that is, there is a strong relationship between networks in the host country and remittance flows to Bangladesh.

Other factors might also shape remittance propensities, such as the cost of transfer and other macroeconomic factors. Ahmed et al. (2021) examined whether and to what extent the reduction in the cost of sending remittances increases the flow of remittances to developing countries. The study indicated a 1% decrease in the cost of remitting USD 200 leads to about a 1.6% increase in remittances. Empirical considerations also suggest that macroeconomic variables influenced remittance flows. Frankel (2011), Ruiz and Vargas-Silva (2010) and Mohapatra et al. (2010) found a positive relationship between remittances and the GDP of the countries. Abbas et al. (2017) examines the impact of economic factors in Pakistan on remittances and found that inflation has a significant and inverse relation with remittances. Also, exchange rate regimes are likely to determine remittance flows (Akçay & Karasoy, 2019; Panda & Trivedi, 2015).

3 MODEL

To analyse the effect of interest rate on remittance flows, the study will employ the remittance-saving model in which a migrant worker has only two periods in allocating their resources. The two periods – period t (present or today) and period t+1 (future or tomorrow) model is sufficient to analyse the dynamic behaviour and considerably simplifies the analysis. In this two-period model, a (legal) migrant worker consumes, saves, and sends remittances in both periods, while optimizing their lifetime utility. He/she migrant earns income in the present and the future (for

simplicity, we assume that future income is known with certainty). The migrant can save or borrow at some (real) interest rate (impossible for illegal migrant workers). The study will analyse the migrant's problem algebraically using calculus and an indifference curve - budget line diagram.

We begin with a general migrant's problem, which can be expressed as follows:

$$\max_{C_t, C_{t+1}, R_t, R_{t+1}} \quad U = u(C_t) + \beta u(C_{t+1}) + u(R_t) + \beta u(R_{t+1}) \qquad 0 < \beta < 1 \tag{1}$$

Equation (1) represents the utility maximization function of a migrant worker at both periods, including the discount factors β. The migrant maximizes their utility obtained from consumption in the host countries, and also maximizes their utility from sending remittance to their home countries. Notice that instead of using consumption by remittance recipients in the home countries in function (1), the study uses remittances R_t and R_{t+1} to represent the amount of consumption as it equals remittances sent by the migrant. Utility obtained by a (altruistic) migrant from sending remittances is the satisfaction they get from seeing their family members being better off. Therefore, although the decision on consumption in the home countries is made by the recipients, the migrant is satisfied with their choices.

At time t, a migrant worker's budget constraint is:

$$C_t + S_t + R_t + \omega_t R_t \leq Y_t\,, \quad \omega_t > 0$$

$$C_t + S_t + (1 + \omega_t) R_t \leq Y_t\,, \quad (1 + \omega_t) > 1$$

Here ω_t is total cost (or price) of remittance transfer (per unit), which might change due to the change in demand for transfer services. R_t is the amount of remittance that a migrant is going to send to their home countries at time t. So, $(\omega_t)R_t$ is the total cost of sending remittances. S_t is the stock of saving (the term "savings" will be used throughout the paper to refer to the stock of saving).

At time t+1, the budget constraint can be written as:

$$C_{t+1} + S_{t+1} + R_{t+1} + \omega_{t+1} R_{t+1} \leq Y_{t+1} + (1 + r_t) S_t, \;\; \omega_{t+1} > 0$$

$$C_{t+1} + S_{t+1} + (1 + \omega_{t+1}) R_{t+1} \leq Y_{t+1} + (1 + r_t) S_t, \;\; (1 + \omega_{t+1}) > 1$$

Notice that r_t is interest rate in the host country.

Rearrange equation,

$$C_{t+1} + S_{t+1} - S_t + (1 + \omega_{t+1}) R_{t+1} \leq Y_{t+1} + r_t S_t$$

Assume that the financial institutions from which the migrant borrows do not allow them to borrow in the period t+1. This implies that they are not allowed to die in debt. A further assumption is that migrants will consume/remit all the remaining saving at period t+1. Hence, the migrant's saving at period t+1 is set to equal zero.

$$S_{t+1} = 0$$

Hence, we can write the two flow budget constraints in equality form as follow:

$$C_t + S_t + (1 + \omega_t) R_t = Y_t$$
$$C_{t+1} + (1 + \omega_{t+1}) R_{t+1} = Y_{t+1} + (1 + r_t) S_t \tag{2}$$

Solve for S_t,

$$S_t = \frac{C_{t+1}}{1 + r_t} + \frac{(1 + \omega_{t+1}) R_{t+1}}{1 + r_t} - \frac{Y_{t+1}}{1 + r_t} \tag{3}$$

Plug (3) into (2) and rearrange,

$$C_t + \frac{C_{t+1}}{1+r_t} + (1+\omega_t)R_t + \frac{(1+\omega_{t+1})R_{t+1}}{1+r_t} = Y_t + \frac{Y_{t+1}}{1+r_t} \quad (4)$$

Notice that β in (1) is the utility discount factor whereas $\frac{\mathbf{1}}{\mathbf{1+r_t}}$ in (3) and (4) is a goods discount factor.

The change of endogenous variables $R_t, R_{t+1}, C_t, C_{t+1}, S_t, S_{t+1}$ will depend on the change of exogenous variables $Y_t, Y_{t+1}, \omega_t, \omega_{t+1}, r_t, r_{t+1}$.

4 REMITTANCE-SAVING MODEL

To explain how a migrant behaves regarding sending remittances, the study employs Remittance-Saving Model in which consumption is held constant. By setting consumption variable constant, the first two terms of function (1) become zero when taking partial derivative with respect to remittances.

Therefore, a migrant's problem becomes,

$$\max_{R_t, R_{t+1}} U = u(R_t) + \beta u(R_{t+1}) \ , \quad 0 < \beta < 1$$

And, subject to constraint,

$$C_t + S_t + (1+\omega_t)R_t = Y_t$$
$$C_{t+1} + (1+\omega_{t+1})R_{t+1} = Y_{t+1} + (1+r_t)S_t$$

To explain the effect of exogenous variable on remittances, we assume that consumption at t and t+1 to be constant. That is $C_t = C_{t+1} = \bar{C}$. Then equation (4) become:

$$\bar{C} + \frac{\bar{C}}{1+r_t} + (1+\omega_t)R_t + \frac{(1+\omega_{t+1})R_{t+1}}{1+r_t} = Y_t + \frac{Y_{t+1}}{1+r_t} \quad (5)$$

$$R_{t+1} = \frac{Y_t(1+r_t)}{(1+\omega_{t+1})} + \frac{Y_{t+1}}{(1+\omega_{t+1})} - \frac{(1+\omega_t)(1+r_t)}{(1+\omega_{t+1})}R_t - \frac{\bar{C}(r_t+2)}{(1+\omega_{t+1})} \quad (6)$$

Equation (6) can be written as follow:

$$(1+\omega_{t+1})R_{t+1} + (1+\omega_t)(1+r_t)R_t = Y_t(1+r_t) + Y_{t+1} - \bar{C}(r_t+2) \quad (7)$$

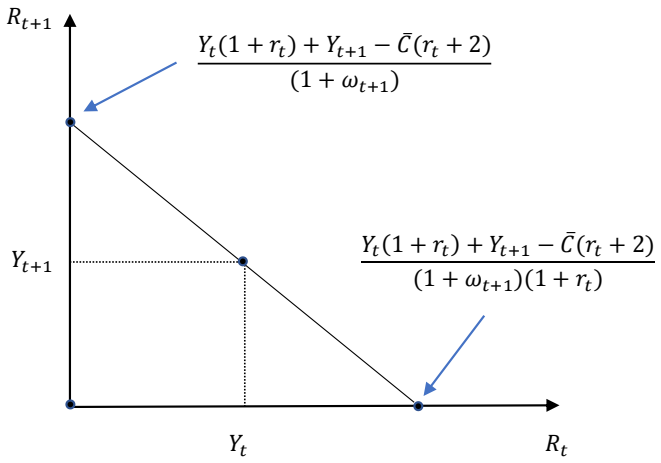

Fig. 1 – Intertemporal Budget Constraint of a (Legal) Migrant Worker. Source: own research

Figure 1 indicates the intertemporal budget constraint that a migrant has when deciding how much remittances he/she should send. If he decides not send remittance at period t, then the

total remittance will be sent in period t+1 will be $\frac{Y_t(1+r_t)+Y_{t+1}-\bar{C}(r_t+2)}{(1+\omega_{t+1})}$. In contrast, if he decides not to send in period t+1, the total amount of remittances he will send in period t will be $\frac{Y_t(1+r_t)+Y_{t+1}-\bar{C}(r_t+2)}{(1+\omega_{t+1})(1+r_t)}$. The region on below the budget line is feasible – a migrant can choose a bundle in this region. However, the region above the line is not.

We specify the determinant of remittances in both periods as follows:

At period t,

$$R_t = f(Y_t, Y_{t+1}, \omega_t, \omega_{t+1}, r_t, r_{t+1})$$

At period t+1,

$$R_{t+1} = f(Y_t, Y_{t+1}, \omega_t, \omega_{t+1}, r_t, r_{t+1})$$

4.1 Euler Equation and Optimization

The analysis will employ the Euler equation, a dynamic first-order condition for an agent's problem optimization. However, the condition is not enough as it does not represent the consumption or remitting function which fails to tell how much to remit in the present or future. Therefore, the change in an exogenous variable will be explained graphically, by using indifference curve/ budget line diagram.

Assume a migrant's problem is:

$$\max_{R_t, R_{t+1}} U = u(R_t) + \beta u(R_{t+1}) \ , \quad 0 < \beta < 1 \tag{8}$$

Replace future remittances in (9) with (6), utility function (9) becomes:

$$\max_{R_t, R_{t+1}} U = u(R_t) + \beta u(\frac{Y_t(1+r_t)}{(1+\omega_{t+1})} + \frac{Y_{t+1}}{(1+\omega_{t+1})} - \frac{(1+\omega_t)(1+r_t)}{(1+\omega_{t+1})} R_t - \frac{\bar{C}(r_t+2)}{(1+\omega_{t+1})})$$

$$\frac{\partial U}{\partial R_t} = u'(R_t) + \beta u' \left[\frac{Y_t(1+r_t)}{(1+\omega_{t+1})} + \frac{Y_{t+1}}{(1+\omega_{t+1})} - \frac{(1+\omega_t)(1+r_t)}{(1+\omega_{t+1})} R_t - \frac{\bar{C}(r_t+2)}{(1+\omega_{t+1})}\right]$$

$$\frac{\partial U}{\partial R_t} = u'(R_t) + \beta u'(R_{t+1}) \left[-\frac{(1+\omega_t)}{(1+\omega_{t+1})}(1+r_t)\right]$$

Set $\frac{\partial U}{\partial R_t} = 0$, we have Euler Equation specified as follows:

$$u'(R_t) = \beta u'(R_{t+1}) \left[\frac{(1+\omega_t)}{(1+\omega_{t+1})}(1+r_t)\right] \tag{9}$$

Rearranging, equation (9) can be written:

$$\frac{u'(R_t)}{\beta u'(R_{t+1})} = \frac{(1+\omega_t)}{(1+\omega_{t+1})}(1+r_t)$$

$\frac{(1+\omega_t)}{(1+\omega_{t+1})}(1+r_t)$ is called marginal rate of substitution (MRS).

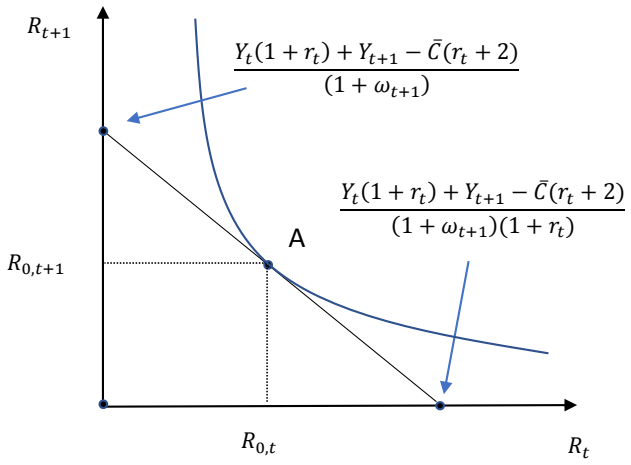

Fig. 2 – Indifference Curve of a (Legal) Migrant Worker. Source: own research

5 INCREASES IN INTEREST RATE IN THE CURRENT PERIOD

This part explains how the change in interest rate in the host countries affects the remittance behaviour of immigrant workers. In this analysis, we assume that migrant is documented who has access to the financial services in the host country. As illegal migrant workers cannot access financial services, the interest rate will not affect the remittance behaviour of illegal migrant workers. In this analysis, we assume first the (legal) migrant is borrowing then the saving migrant. In this study, we hold the exogenous variables constant, except interest rates in the current period. Therefore, the remittance functions can be rewritten as:

At period t,

$$R_t = f(\bar{Y}_t, \bar{Y}_{t+1}, \bar{\omega}_t, \bar{\omega}_{t+1}, r_t, \bar{r}_{t+1})$$

At period t+1,

$$R_{t+1} = f(\bar{Y}_t, \bar{Y}_{t+1}, \bar{\omega}_t, \bar{\omega}_{t+1}, r_t, \bar{r}_{t+1})$$

5.1 Borrowing Legal Migrant Workers

According to Figure 3, an increase in interest rate pivots the budget line through the endowment point and through which the new budget line intersects with the initial one, making the budget line steeper. Note that the hypothetical line (orange) represents the substitution effect which shows how the remittance bundle changes in response to the change in the interest rate while the migrant is given sufficient income so that his lifetime utility remains the same. Figure 3 indicates that the movement of hypothetical line caused by an increase in interest rate in the current period allow the migrant to achieve the same lifetime remittance bundle where he would choose to send smaller remittances in the current period and more in the future period. In other word, the movement of the hypothetical allow the migrant to substitute away from the relatively costly remittances in the current period and into the relatively less costly remittances in the future period.

However, the change in interest rate does not only has the substitution effect, but also income effect. The hypothetical line allows the migrant to have a remittance bundle that leaves his lifetime utility unchanged, but the bundle lies outside the feasible area (above the new budget line). The income effect is the movement from the hypothetical bundle to the new bundle where the new budget line tangent to the new indifference curve. As income effect and substitution effect go in the same direction when interest rate increases, remittances drop in the current period from $R_{0,t}$ to $R_{1,t}$. In the future period, however, change in remittances is unclear as the

substitution effect says it should increase, whereas income effect says it should drop. So, for the future remittances R_{t+1}, knowing the domination of one of these effects is important.

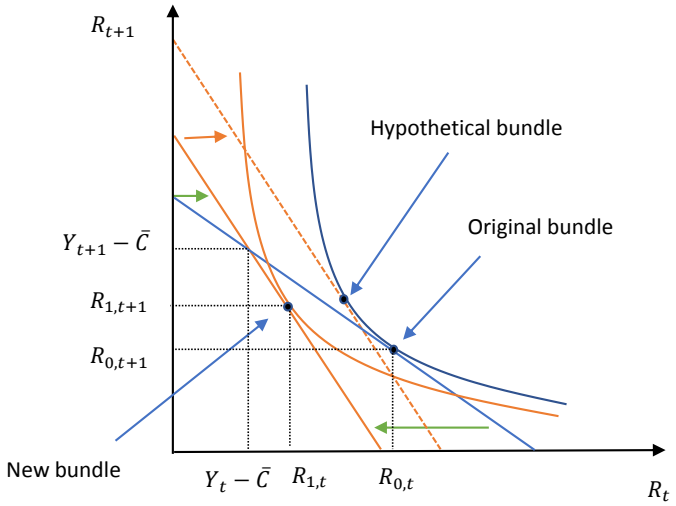

Fig. 3 – Remittance Behaviour of a Borrowing Legal Migrant Workers. Source: own research

5.2 Saving Legal Migrant Workers

We have assumed that the immigrant is a borrowing. Let us now look at how a saving migrant worker respond to the change in interest rate. Graphically, the saving migrant choose the remittance bundle $(R_{0,t}, R_{0,t+1})$, where initial remittances are less than income (after consumption), $R_{0,t} < Y_t$. Again, the increase in interest rate in the current period pivots the budget line through the endowment point. Note that the new bundle stands on the left of the new endowment point. In Figure 4, the substitution effect, represented by the hypothetical budget line, increases remittances in the future period, but reduces remittances in the current period. On the other hand, income effect representing movement of hypothetical bundle to the new bundle shows that remittances increase in both periods. As income and substitution effects go in the same direction at period t+1, we could say that remittances increase in the future period. However, Figure 4 indicates unclear change at period t. Income effect at period t has remittances increasing, in contrast to substitution effect, that say it should decrease. Again, it is important to understand which effect dominates the other.

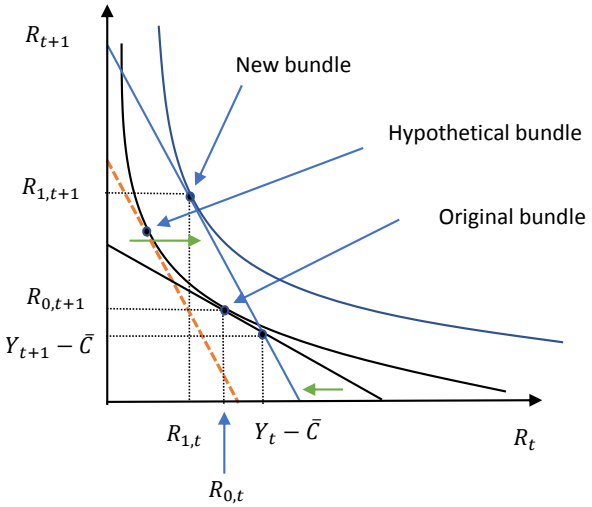

Fig. 4 – Change in Interest Rate for a Saving Legal Migrant Workers. Source: own research

Table 1 summarizes the change in remittances in both periods due to the increase in interest rate. Remittances at period t decrease when interest rate rise for the case of borrowing migrants. However, it is ambiguous if he is a saver. At period t+1, the change in remittances is unclear in response to the increase in interest rate for the borrowing migrant, but it will rise due to the increase in interest rate for the saving migrant.

Tab. 1 – Summary of Changes in Remittances due to the Increase in Interest Rate at Period t. Source: own research

		Substitution effect	Income effect	Total effect
R_t	Borrower	-	-	-
	Saver	-	+	Unclear
R_{t+1}	Borrower	+	-	Unclear
	Saver	+	+	+

6 CONCLUSION

The purpose of the study is to examine how interest rates in Thailand influence remittance flows to the CLM countries by using two-period remitting-saving framework. In the model, the migrant earns income in the present and the future (for simplicity, we assume that future income is known with certainty. The migrant can save or borrow at some (real) interest rate rt, which it takes as given. At period t, the migrant must choose how much to remit and save, while holding consumption constant. The study analysed the migrant's problem both algebraically using calculus and using an indifference curve - budget line diagram. The key insights from the model are as follows. First, the increase in interest rate reduces remittance flows in the current period, while the flows in the future period are ambiguous for the case of borrowing (legal) migrants. Second, for the saving migrants, the rise in interest rate in the current period increase remittance flows in the future, while the current flows are unclear. Third, remittances sent by illegal migrants are expected to be free from interest rate policies.

Although the framework included important factors that influence remitting behaviour of migrant workers, it fails to incorporate other important determinants that might shape the remittance behaviour of migrant workers such as household income and interest rate in the home countries. Second, we keep our endogenous variable consumption constant which is unrealistic. Other personal characteristics of immigrant workers such as financial literacy of immigrants and language have not been included in the model. Despite limitations, the study provides a contemporary contribution to the theoretical literature. This study suggests further investigation empirically and theoretically on factors in the home origin of immigrants that might influence their remittance behaviour.

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FOND MALÝCH PROJEKTOV

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ADOPTIONS OF INDUSTRY 4.0 AND CIRCULAR ECONOMICS FOR GREEN LOGISTICS AND SUSTAINABLE SUPPLY CHAIN: A PROPOSED RESEARCH FRAMEWORK FOR VIETNAM INDUSTRY

Thanh Van LUU

Abstract

Human activities, in general, are increasingly destroying the Earth and the global ecosystem. Vietnam enterprises are in a shortage of trained human resources with specialized knowledge of logistics and supply chain, to solve the problems arising in their operations along with the trend of green and sustainable mindset and industry 4.0 applications. The main aim of the research is to investigate the impact of Industry 4.0 and Circular Economy on Vietnam's Green Logistics & Sustainable Supply Chain operations.

The research consists of three stages: (1) a literature review of industry 4.0, circular economy, green logistics, and sustainable supply chain is developed; (2) a research framework that integrates the circular economy variables, industry 4.0 applications, green logistics, and sustainable supply chain operations is proposed with some main research hypotheses being developed; (3) future agendas are outlined in which quantitative methods are used, such as statistical tool and multicriteria decision making approaches. The main goal of this paper is to design a research framework for green logistics and sustainable supply chain applications. The proposed framework benefits Vietnam's enterprises, especially in terms of the adoption of the circular economy and industry 4.0 in their business operations. It also contributes to the orientation of a workforce training plan for Vietnam's logistics and supply chain fields. The scope of the study is specifically focused on green logistics and sustainable supply chain areas; however, variables for other industries such as manufacturing require further investigation.

Keywords: *Circular Economy (CE), Industry 4.0 (ID4.0), Multi-Criteria Decision Making (MCDM), Green Logistics (GL), and Sustainable Supply Chain (SSC)*

1 INTRODUCTION

1.1 Motivation

The world economy has been severely affected by the COVID-19 pandemic, and Vietnam is no exception due to its extensive economic integration, but over the past time, Vietnam has also demonstrated remarkable resilience, through proactive countermeasures at both the central and local levels. As the Vietnam Economy Data (General Statistics Office, 2020), this stability is reflected in its macroeconomic indicators, such as total GDP growth in 2020 at 2.91%, the lowest level in at least two decades, and very far from the average of 6.76% during 2015-2019; however, Vietnam is one of the few countries in the world that do not forecast an economic recession.

Vietnam is experiencing rapid changes in demographic and social structure. Vietnam's population has grown to approximately 97.3 million in 2020 and is expected to increase to 120 million by 2050. Overall, the unemployment rate is reduced over time to 2.2% in the year 2019 and slightly increased to 2.51% in 2020. According to the Vietnam Census in 2019, 55.5% of the population is under 35 years of age, with an average life expectancy of almost 76 years, which is higher than other similar income countries in the region. This is the abundant human resource that contributes to the Vietnam labour market. However, the population is rapidly

aging. Vietnam also needs to improve the qualifications of its workforce to create more productive jobs on a large scale in the future.

According to WTO commitments, Vietnam opened the logistics market in 2014. Compared to the period before joining the WTO, Vietnam's logistics has grown significantly in the number of participating companies and the professionalism of service providers. The Vietnam Logistics Research and Development Institute (VLI) shows that there are approximately 3,000 companies in Vietnam operating in the field of logistics in general and needs more than 200,000 employees by 2030, meanwhile the ability to meet the needs of logistics human resources is only about 10% of the market demand (Vietnam Logistics Research and Development Institute, 2019).

Vietnam with a system of more than 30 seaports, 6 international airports, the volume of cargo exploited through ports has increased on average 10% per year since 2007. The total cost of logistics is estimated from 20.9% - 25% of GDP, which is more than double to triple the rate of logistics in the Japan and USA (see Fig. 1).

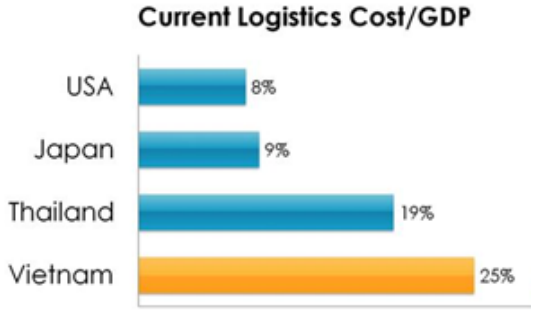

Fig. 1 – Logistics Cost Comparison. Source: Logistics4VN (2015)

According to Decision No. 175/QD/TTG of Vietnam's Prime Minister on 'Approving the Vietnam general strategy to develop the service sector by 2020, vision to 2030', the growth rate of the logistics market reaches 20% to 25%, the total value of logistics services is projected to account for 10% of GDP. Logistics is considered a key factor in promoting the development of production and distribution systems. This shows that the logistics industry and the development of its human resources have become the national program.

The Vietnamese government is trying to minimize the impact of economic growth on environmental and social issues. Green and sustainable development strategies and models have begun to receive special attention. In addition, key performance measures and indicators for the mitigation and adaptation of climate change have also been developed to cope with extreme weather and natural disasters through the implementation of the Nationally Determined Contribution (NDC). According to the Minister of Natural Resources and Environment of Vietnam, Tran Hong Ha: 'We have also identified that the model of a green economy, a low-carbon economy, such as a circular economy is a key task to contribute to a sustainable economic restructuring. We are determined to change the economy from brown energy to green energy, unsustainable to sustainable development. (Quan, 2021)

At the seminar on the "Training Program of Logistics and Supply Chain Management" organized by the Department of Industrial Systems Engineering of the International University of Vietnam National University in Ho Chi Minh City on 06 November 2013, fourteen companies were surveyed about the current situation and the needs for human resources in logistics and supply chain field. The results of this survey showed that the human resource needs for this field are enormous, and it is necessary to develop a training program in the future. The survey also found that when dealing with difficulties in logistics and supply chain operations, enterprises rely mainly on their feelings and experience. Problems that cannot be

solved by themselves are based on external experts or consulting firms. Thus, it can be affirmed that at present Vietnam's enterprises are in a shortage of trained human resources with specialized knowledge of logistics and supply chain, to solve problems that arise in their operations along with the new trend of a green and sustainable mindset. This research is motivated by the growing interest in industry 4.0, the circular economy model in the areas of green logistics and sustainable supply chain in Vietnam.

1.2 Problem Statement - The need for study

Human activity is destroying the Earth increasingly. The global ecosystem is under threat and is shrinking. This can be illustrated by the shrinking of the earth due to fallowing land, rising sea levels, growing populations, increasing cattle numbers, and per capita consumption at once, reducing biodiversity at a rapid rate. The IPBES report (Rounsevell et al., 2018) stated that 'The health of ecosystems on which we and all other species depend is deteriorating more rapidly than ever. We are eroding the very foundations of our economy, livelihoods, food security, health, and quality of life worldwide'. The concept of circular economy is one of the most appropriate approaches to achieve sustainability for the future (Hazen et al., 2020).

Humans tried to plan their resources such as time, effort, and costs for any necessary activities. 'Green or sustainable thinking' is gaining strong interest in the community; especially required in company business activities to reduce costs without affecting the environment. Industry 4.0 adoption and a sustainable business mindset are the keys to any business that wants to maximize its benefits within available resources. Therefore, utilizing effective resources is also the social responsibility of a smarter business, which satisfies economic, social, and environmental goals.

To do that, combinatorial optimization and MCDM are the keys to solving real-world problems and conducting research. There is a need for a better understanding of a structured approach for the circular economy model, and the industry 4.0 applications in green logistics and sustainable supply chain aims to balance the three pillars of sustainability, that is, the economic, environmental, and social dimensions. Consequently, companies that have a desire to improve their sustainability performance not only try to maximize their benefits but also concern themselves about the environmental and social externalities of their operations. The research conducts a study on 'Adoption of Industry 4.0 and Circular Economics for Green Logistics and Sustainable Supply Chain: A Proposed Research Framework for Vietnam's Industry'.

More specifically, the following research questions (RQ) need to be addressed:

RQ1: What are CE models and industry 4.0?

RQ2: What are the trends in logistics & supply chain practices and the advancements in research in Vietnam and the world?

RQ3: Why industry 4.0 and CE affect the new trends in logistics & supply chain?

RQ4: How to design an integrated framework of CE and industry 4.0 for GL and SSC?

1.3 Research Objectives

The main objective of the study is developed to make clear the directions of the four RQs formed in the previous section in the light of the green and sustainable perspectives that can be applied in the Vietnam industry and to propose future research agendas.

In particular, the study forms the following research objectives (RO):

RO1: Provide a review of the literature on industry 4.0 and CE models for GL & SSC.

RO2: Propose a research framework for GL & SSC that can be applied in Vietnam.

RO3: Outline future research agendas using combinatorial optimization or MCDM models to determine optimal solutions for transportation or location or warehouse operations problems to achieve from the perspective of sustainability: reducing costs, carbon dioxide emissions, and covid-19 impacts.

2 LITERATURE REVIEW

To develop this section, the author chooses some keywords such as 'Industry 4.0', 'CE', 'GL & SSC', 'sustainability', 'combinatorial optimization + GL & SSC', and 'MCDM + GL & SSC', etc. And then the Web of Science, etc., especially the Journal Ranking Web of Scimago are used to determine and download papers from Q1/Q2 as Journal of Cleaner Production; International Journal of Production Research; International Journal of Production Economics; Computers and Operations Research; Computers and Industrial Engineering; Production Planning & Control; Annals of Operations Research; European Journal of Operational Research; Resources, Conservation & Recycling; Ecological Economics, etc.

The systematic literature review process is developed in Figure 2.

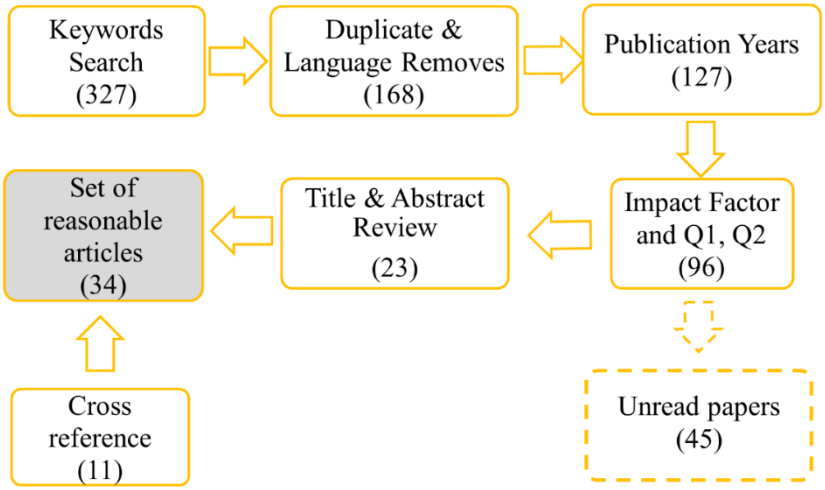

Fig. 2 – Review process of the systematic literature. Source: own research

The keyword search led to a set of 327 articles, of which 159 are duplicated, and in other languages were removed. The selection process continues to consider in the publication years (2017-2021), its impact factor, and Q1/Q2 that selected 96 papers in which more than half are reviewed on the title and abstract with 23 accepted papers, while the remaining 45 papers are stored in the unread folder. The set of 11 papers has been searched from cross-references. Therefore, a total of 34 articles have been selected and analysed for this literacy.

2.1 Industry Revolution 4.0 in Industrial Engineering & Management and Logistics

In the current global economy incorporated with Industrial Revolution 4.0, manufacturing and logistics are revolutionized by providing the opportunity to use advanced technologies. Industrial engineering and logistics are key facilitators of global supply chain and production, which are highly associated with the economic, industrial, and agricultural development of a nation.

Nwaiwu et al. (2020) analysed the five factors that have the greatest impact on the adoption of Industry 4.0 within the Czech manufacturing sector to achieve sustainable process management. The five factors include strategy, organizational fit, competitiveness, operations, and human resources. According to Alkahtani et al. (2018), current trends and advances in industrial

engineering include minimizing energy exhaustion to reduce environmental impact by having smarter design and techniques; application of the Internet of Things (IoT) and cloud computing in smart products, robotics, and automation to lower cost without affecting quality. Furthermore, a subset of industrial engineering & management such as production management, information technology, intelligent systems optimization, operations research, and supply chain management, is getting a potential boost in the future. These trends aim to create a greener lifestyle and reduce the environmental footprint to sustain not only manufacturing but also the global supply chain.

2.2 Relations between Industry 4.0 applications and the CE model of GL & SSC

There are many studies on the relationship between CE and Industry 4.0 and GL & SSC, such as Geissdoerfer (2017) provided conceptual clarity by distinguishing the terms and synthesizing the different types of relationship between circular economy and sustainability. Govindan and Hasanagic (2018) analysed the drivers, barriers, and practices that influence the implementation of the circular economy in the context of supply chains through a systematic review. Seroka-Stolka and Ociepa-Kubicka (2019) presented the relationship between green logistics, using the concept of circular economy and the development of green logistics practices on the example of sludge management. Hazen et al. (2020) discussed how supply chain processes can support the successful implementation of CE. Yadav et al. (2020) developed a framework to overcome SSC challenges through industry 4.0 and circular economy-based solution measures. They identified a unique set of 28 sustainable SCM challenges and 22 solution measures. Bag and Pretorius (2020) expanded the knowledge base by providing a detailed review of Industry 4.0, sustainable manufacturing, and circular economy and proposed a research framework that integrates these three contemporary concepts in the context of supply chain management. Del Giudice et al. (2020) analysed the effect of circular economy practices on firm performance in a circular supply chain and explores the moderating role that the big data-driven supply chain plays within these relationships. To sum up this section, Kumar et al. (2021) through reviews of the literature and expert opinion, identified key criteria and barriers that must be solved to meet sustainable goals. It develops an integrated strategy that promotes sustainable practices through circular economics and industry 4.0 applications.

2.3 Adoptions of Industry 4.0 and Circular Economics in GL & SSC

Modern logistics and supply chain management is a demand for diversified and specialized industrial manufacturing, the availability of scattered global resources, expanded consumer markets, and sustainable requirements. From the first industrial revolution to the present, the supply chain process is continuously evolving and the latest trends in logistics and supply chain activities focus on a ‘green and sustainable’ mindset using smart, technology-driven, and IT-based management to reduce operating costs, environmental impact, and increase efficiency. Green logistics and sustainable supply chain perspective become essential for business operations, such as quality sources of raw materials; efficient production processes; and effective reduce, reuse, and recovery cycles.

Many researchers investigate their efforts on GL & SSC and CE, such as Brandenburg et al. (2014) provided a content analysis of 134 carefully identified papers on quantitative, formal models that address sustainability aspects in the forward supply chain. Korhonen et al. (2018) contributed to the scientific research on CE. Patwa et al. (2021) presented an empirically validated CE adoption model in emerging economies. And Morseletto (2020) examined which targets can facilitate the transition towards a circular economy.

For more details, Zijm et al. (2016) stated that sustainable logistics and supply chains are growing in terms of system status; cultural change; technological innovation; and new business

model development. The first concern of the logistics system is the status of unsustainability due to ecological and social footprint; this poses the need to improve human resource quality and improve productivity by using both technical processes and decision making (AI, machine learning, etc.). The second concern is focused on the shift in consumer behaviour or cultural change. In the third trend, technological innovations are still a trend in logistics and supply chain management; In addition to technical aspects, robotics changes the logistics infrastructure such as automatic storage and retrieval systems (controlled by Warehouse Management Systems), and the Internet of Things is the future of unmanned transportation. The fourth trend is on the development of smart business models such as the CE model or other control mechanisms that have a great attention for ID4.0 applications such as Big Data Analytics towards end-to-end automated decision architectures. Furthermore, the 'Change of mind' is the next big thing in this field considering game theory, which helps a company achieve a stable overall equilibrium solution but sacrifice its optimal one to obtain sustainable logistics.

In recent years, Hussain and Malik (2020) based their research on the organizational sense-making literature to identify organizational enablers of circular supply chains and their relationships with the environmental performance of supply chains. A supply chain is in a significant transformation with the help of technologies, the three biggest trends in 2020 are AI & Machine Learning, Green Logistics, and Big Data Analytics. According to Galea-Pace (2020), the three key ways to tackle the supply chain this year are risk management, responsible sourcing, and supply chain transparency, which also emphasizes an important green approach to customers and company strategies.

2.4 Research Material and Methods

This part looks at some research materials and methods developed for industry 4.0 applications and CE models of GL & SSC. Linear relationships between customers and suppliers are assumed in most research on supply chain management. Supply chains, however, are now complicated and characterized by their networks with the differentiated and autonomous rights of members. The next discussion is on the development of advanced mathematical modelling for the challenges in the solution of supply chain management problems. Mathematical and algorithm approaches are usually assumed in linear programming; mixed-integer, integer linear programming; nonlinear programming; MCDM and goal programming; fuzzy and stochastic programming; heuristics and metaheuristics algorithms in several key research areas such as quality and contract management in the supply chain, inventory management, sourcing and selection of suppliers and strategic partners, supply chain network design, logistics management, and production planning and scheduling.

Since multi-objective optimization was introduced, both mathematical programming and heuristic approaches were proposed to deal with this kind of problem. An application of multi-objective mixed-integer programming is in a multi-section Operating Theater Facility Layout (Chraibi et al., 2014), while Bal and Badurdeen (2020) also presented an MCDM framework for the facility location problem integrating the proposed CE business model. In recent years, Khan et al. (2021) investigated current and emerging trends in the field of sustainable supply chain management that are dominated by MCDM-based research methods. Yamchi et al. (2020) proposed a problem with multi-objectives, such as reducing costs and carbon dioxide emissions and increasing the responsiveness by developing a multi-objective linear model for a sustainable closed-loop agricultural supply chain characterized by a deteriorating product to determine the optimal flow and its facility locations.

However, if the business needs a reasonably good solution in a short amount of time, which is often the case in real-time operational settings, then a heuristic/metaheuristic solution may be the better choice. Feizollahi et al. (2021) developed an efficient genetic metaheuristic algorithm

to solve a multi-objective and NP-hard problem for a closed-loop supply chain network. Kazancoglu et al. (2021) used the fuzzy Decision-Making Trial and Evaluation Laboratory (DEMATEL) method to assess causal relationships among policy-related barriers and then propose a framework that highlights policy-related barriers for a supply chain in the CE transition and discusses the potential impacts on improving corporate environmental performance.

Regarding industry 4.0 applications, Sharma et al. (2020) presented a systematic review of machine learning applications in the agricultural supply chain. Blockchain technology is also widely used (Lopes de Sousa, Jabbour, et al., 2018; Manavalan & Jayakrishna, 2019; Saberi et al., 2019; Bag & Pretorius, 2020; Kouhizadeh et al., 2020; Nwaiwu et al., 2020; Yadav et al., 2020; Kumar et al., 2021), such as Kouhizadeh et al. (2020) examined how blockchain technology is likely to transform and advance circular economy realization. Using grounded theory built from multiple case studies, the research presents early evidence linking the blockchain application to the circular economy dimensions of regenerate, share, optimize, loop, virtualize, and exchange (ReSOLVE model). While Saberi et al. (2019) investigated the application of blockchain technology and smart contracts to sustainable supply chain management, taking into account the pressures of local and global government, community, and consumers to meet sustainability goals. Jabbour et al. (2019) made the case for the integration of the circular economy and large-scale data (LD), also known as big data.

Some researchers use the AHP principle in their work (Torasa & Mekhum, 2020; Khan & Zhang, 2021). Khan and Zhang (2021) proposed China's regional green logistics development evaluation system based on circular economy theory, to provide a measure of green logistics development at the regional economic level, according to the AHP principle. Furthermore, Torasa and Mekhum (2020) assumed among the initial contributions in the field of green logistics activities and their impact on the various indicators of circular economy in the ASEAN region using the AHP technique.

3 METHODOLOGY

In the first stage, the research focuses on a qualitative methodology that produces a literature review on Industry 4.0 and CE models for GL & SSC, which was useful for the second stage to propose a conceptual research framework that can be applied in Vietnam.

Based on this understanding of the proposed research framework, a future research agenda is outlined in the third stage using combinatorial optimization and MCDM to model and optimize a transportation, location, or warehouse operations problem. Quantitative methods are used in future work that involves the use of a survey questionnaire or observation or interview to collect data and perform statistical analysis, MCDM, and/or AHP techniques.

As a result, the conceptual research design is developed in Figure 3.

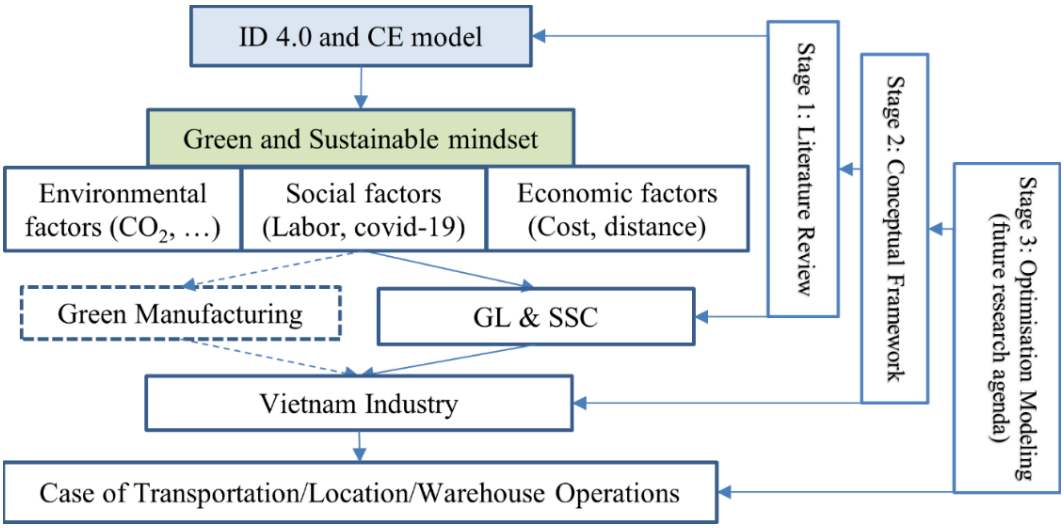

Fig. 3 – Conceptual Research Design. Source: own research

3.1 CE and Industry 4.0 Background

The Ellen McArthur Foundation (MacArthur, 2020) considered circular economics an ecological economy that utilizes ecosystem cycles to restore and regenerate industrial ecology by redesigning production-service systems. This is a systematic approach to satisfy economic, social, and environmental objectives. A circular economy is based on reduce-reuse-recycle principles to minimize resource consumption and waste.

The circular economy claimed by Preston (2012) that the Industrial Ecology, which was first developed in the 1970s, is the root of CE nowadays. CE could be defined as an economic model to use the resource with a minimal closed-loop system of products. CE has the potential to grow sustainability.

Some CE frameworks are developed as 3R (i.e., reduce, reuse, and recycle) (Patwa et al., 2021), 4R (i.e., reduce, reuse, recycle, and recovery/renewing), 10R (Morseletto, 2020), and ReSOLVE (Lopes de Sousa Jabbour et al., 2018; Jabbour et al., 2019), etc.

As a result of the above discussions, there is a need to enable and influence the growth of CE in Vietnam, an emerging economy, especially in government policies; industry 4.0 adoption (High-tech applications such as blockchain, AI, etc.,); and its framework.

3.2 Logistics and Supply Chain Background

Simchi-Levi et al. (2008) defined supply chain management as the management of a multi-echelon level in a 'supply-produce-distribute-sell' network by planning, organizing, and controlling information and material flows to optimize supply chain partners' operations to minimize their costs and improve customer service at a higher reliable level.

No model has been taken as standard in the trend of globalization. Depending on economic potential, the level of science and technology (level of high-tech application), and the national topography and policy, each country determines its development strategy, as well as selects the appropriate model to achieve high market efficiency and effectiveness; in addition, it provides convenience for social and environmental sustainability. This research argues that GL & SSC is a high-tech industry with two distinct attributes: engineering - technology and economics - commerce, and more investigation is done on two variables identified as the configuration and collaboration of logistics & supply chain network (SC). Therefore, the concept of GL and SSC is developed along with CE and Industry 4.0.

3.3 Relationships about Circular Economy and Sustainability

The relationship between CE and sustainability is based on the approach method to enhance the dependence between economics, society, and the environment, but can be undertaken using different approaches and methodologies (Moreno et al., 2016; Geissdoerfer et al., 2017). The main difference between CE and sustainability is that sustainability may focus more on integrating the economy, society, and environment, presenting the three as equal factors. Although CE focuses more on economic priorities which bring economic benefits to society and the environment and can be seen as a more business-centric approach.

4 RESULTS

4.1 Proposed Research Framework

In summary, from the results of the literature review and research background, the study considers focusing on only two variables in GL & SSC: SC configuration and collaboration.

In addition, the study examines the adoption of integrated industry 4.0 and CE system in Vietnam, a developing country in three independent variables, such as the CE framework (e.g., 3R: reduce-reuse-recycle), high-tech applications (AI, big data analysis, machine learning, IoT, blockchain, etc.), and government policies/regulations in Vietnam that promote the development of principles of CE models and industry 4.0 applications in the areas of GL & SSC.

The research framework is proposed in Figure 4.

4.2 Research Hypothesis

The multiple aspects lead to some hypotheses for RQ1 and RQ2:

H1: 'The CE framework positively affects the adoption of ID4.0 & CE in Vietnam'.

H2: 'High-tech application positively affects the adoption of ID4.0 & CE in Vietnam'.

H3: 'Government policy positively affects the adoption of ID4.0 & CE in Vietnam'.

H4: 'SC collaboration positively affects the environmental goal of GL & SSC'.

H5: 'SC configuration positively affects the environment goal of GL & SSC'.

To answer RQ3, hypotheses of the integration of ID4.0 & CE adoption and GL & SSC are developed:

H6: 'Adopting ID4.0 & CE positively affects SC collaboration'.

H7: 'Adopting ID4.0 & CE positively affects SC configuration'.

H8: 'Adopting ID4.0 & CE positively affects GL & SSC'.

Think of RQ4, this leads to the hypothesis:

H9: 'GL & SSC practices have a positive relationship with ID4.0 & CE adoption'.

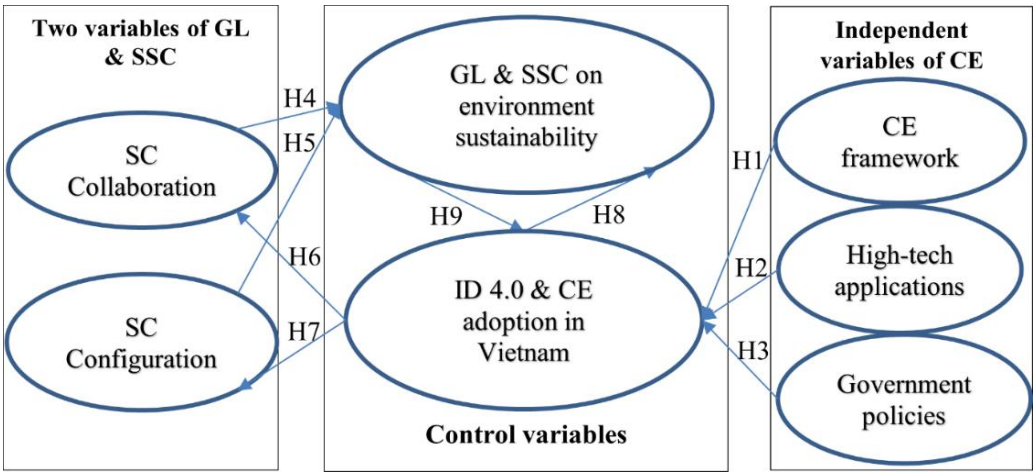

Fig. 4 – Proposed research framework. Source: own research

5 DISCUSSION

5.1 Expected benefits for theory

Circular economics, Industry 4.0, and green logistics & sustainable supply chain are three main areas of knowledge. Knowledge and deployment of high-tech applications such as blockchain and AI technology in Vietnamese enterprises are scarce. The study has contributed mainly to the proposal of a theoretical framework of ID4.0 and CE models in green logistics and sustainable supply chain fields (see Fig. 4). Future research agendas are outlined with quantitative methods used, using statistical analysis tools to evaluate and validate the hypotheses of the proposed research framework, and then a mathematical model and algorithm are developed using MCDM or AHP techniques to optimize a selected problem on transportation or location or warehouse operations in Vietnam industry (see Fig. 3). A questionnaire, observation, and interview techniques are used for primary data collection in quantitative methods. Secondary data are also considered in a real case.

5.2 Expected benefits for practice

The current study offers more practical solutions. The research framework benefits Vietnam's practitioners, especially in terms of the adoption of ID4.0 and CE of GL & SSC that reduce the gaps with developed countries. It also contributes to the development of skilled workforces for the Vietnam industry, especially in logistics and supply chain operations in the light of the ID4.0 and CE business models.

5.3 Limitation

First, the study mainly deals with data access problems. In this situation, the author may ask for the help of friends who are now working as managers/ directors in different FDIs and SMEs in Vietnam. Second, the scope of the study is focused specifically on the logistics and supply chain areas; the validity of the results for other industries, such as manufacturing, might require further investigation. Finally, there is a gap between Vietnam and other developed countries, and it is also a challenge to refer research papers from developed countries to apply to Vietnam, an emerging and developing country.

6 CONCLUSION

In the current business environment of Industry 4.0 and the circular economy, improving logistics and supply chain processes in Vietnam is an urgent and practical task, especially with the goal of green and sustainable development. Vietnamese companies are coping with high-tech challenges, new business models, and government policies. Therefore, it is necessary to adopt an integrated conceptual framework of ID4.0 and CE for GL and SSC. This study produces a literature review and proposes a research framework with five variables considered, such as government policy, high-tech application, CE framework, collaboration, and configuration of GL & SSC. This framework can be used to develop a strategic plan for training the workforce for the Vietnam industry.

As a result, future research agendas are also proposed: a) statistical analysis and validation of the hypotheses of the proposed framework; b) optimal modelling and algorithm for a selected case study of logistics and supply chain fields in Vietnam on transportation, location, and warehouse operations problems in the light of sustainable perspectives.

Acknowledgement

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INTERREG V-A SK-CZ 14-20 SLOVENSKÁ REPUBLIKA ČESKÁ REPUBLIKA

EURÓPSKA ÚNIA EURÓPSKY FOND REGIONÁLNEHO ROZVOJA SPOLOČNE BEZ HRANÍC

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THE ROLE OF CUSTOMER RELATIONSHIP MANAGEMENT (CRM) AND THE RELATION BETWEEN TEAM INNOVATION AND TEAM PERFORMANCE: A LITERATURE REVIEW

Hanh Thi My Ly, Tho Huu Hoang Nguyen

Abstract

Customer relationship management (CRM) has become the fastest topic for business management solutions in recent years, making CRM a critical marketing strategy for businesses seeking sustainable success in business over time. Although the literature on CRM has been growing, published studies have paid little attention to the study of CRM practices. Their role in team performance is critical to organizations developing a customer-centric strategy. Thus, our work aims to fill this research gap. The systemic search methodology collects data from books, journals, and conferences from credible sources. Drawing on opportunity-ability-motivation (OAM) theory, existing literature on CRM practices, and team performance, the findings of the reviews are to propose a conceptual framework for the aviation industry. The framework clarifies (1) the vital role of knowledge sharing in CRM through the customer-centred approach of modern marketing approaches (2) the direct effects of CRM practices (knowledge sharing, customer involvement, long-term partnership, joint problem solving, technology-based CRM) on team innovation and (2) mediating effect of team innovation on the relationship between CRM practices-team performance. This research work contributes to the existing literature in extending OAM theory to investigate the CRM practices-team performance relationship and (2) the theory to explore the mediating effect of team innovation that gives a theoretical suggestion to scholars working in marketing and aviation management.

Keywords: *Customer relationship management (CRM), Innovation, CRM practices and team innovation, team innovation, team performance*

1 INTRODUCTION

The three Customer Relationship Management (CRM) modules (sales, marketing, and services) are a definitive tool to obtain better business results through the customer-centred approach of modern marketing theories (Guerola-Navarro et al., 2021b). Customer Relationship Management (CRM) is a technological solution that emerged in the 1970s as a tool for companies to automate the management of the company's internal sales force (Buttle, 2004). Customer relationship management (CRM) combines people, processes, and technology that seeks to understand a company's customers. It is an integrated approach to managing relationships by focusing on customer retention and relationship development. CRM has evolved from advances in information technology and organizational changes in customer-centric processes. Companies that successfully implement CRM will reap customer loyalty and long-run profitability (Chen & Popovich, 2003).

CRM technology applications link front office (e.g., sales, marketing, and customer service) and back office (e.g., financial, operations, logistics, and human resources) functions with the company's customer "touchpoints" (Fickel, 1999). A company's touchpoints can include the Internet, e-mail, sales, direct mail, telemarketing operations, call centres, advertising, fax, pagers, stores, and kiosks. These touchpoints are controlled by separate information systems. CRM integrates touch points around a standard view of the customer (Eckerson & Watson, 2000). We believe that CRM is not simply a technology application for marketing, sales, and

service. Instead, a cross-functional, customer-driven, technology-integrated business process management strategy maximizes relationships and encompasses the entire organization (Goldenberg, 2000).

A CRM business strategy uses marketing, operations, sales, customer service, human resources, R&D, finance, information technology, and the Internet to maximize the profitability of customer interactions. CRM offers customers customization, simplicity, and convenience to complete transactions, regardless of the channel used for exchange (Gulati & Garino, 2000). CRM applications help organizations assess customer loyalty and profitability in measures such as repeat purchases, dollars spent, and longevity. CRM applications help answer questions such as "What products or services are important to our customers? How should we communicate with our customers? What are my customer's favourite colours, or what is my customer's size?" In particular, customers benefit from the belief that they are saving time and money and receiving better information and special treatment (Kassanoff, 2000).

Innovation plays a vital role in organizational achievement as we understand that innovation is not a new phenomenon. Arguably, it is as old as humanity itself. However, innovation has not always received the academic attention it deserves despite its obvious importance. This is now rapidly changing. However, research on the role of innovation in economic and social change has proliferated in recent years, particularly within the social sciences, and often with a bent toward cross-disciplinarily (Fagerberg, 2004). For many years, the aviation industry has been known as one of the industries that introduced significant innovations in many different areas. These innovations include technological transformations, safety procedures, and economic deregulation, allowing connections worldwide to take place in hours rather than days, shrinking distances, and opening possibilities for mass tourism (Lohmann & Pereira, 2019). The challenges the aviation sector will face will require the instigation of new provisions, particularly in terms of advances supporting more sustainable displacement of travellers and a reduction in carbon emissions and waste, while at the same time offering more personalized and comfortable services in a safer and more secure environment (International Air Traffic Association (IATA), 2022).

When considering predictions for the coming decades, many concerns related to safety and security remain. New solutions likely include recent technological trends, new virtual reality solutions; augmented reality environments; green environmental solutions. Team innovation is considered an essential factor for organizational effectiveness. However, fostering innovation in teams remains a significant challenge for team leaders. Some authors also mention that today's organizations have to foster innovation to ensure their competitive advantage in the marketplace (Anderson et al., 2014; van Knippenberg, 2017; Zhou & Hoever, 2014). Most of the innovative work in organizations is performed by teams, particularly in knowledge-intensive industries (Anderson et al., 2014; Thompson & Choi, 2006; West, 2002).

Team performance is an important indicator to measure CRM practices and team innovation in aviation construction. However, there remains a lack of understanding in the aviation industry related to the conditions in which CRM practices impact team performance. Few studies on the models of CRM practices, team learning, team innovation, and team performance models (Rahmadani et al., 2020; Guerola-Navarro et al., 2021a). Past studies have proved that CRM practices can affect performance and innovation, while team learning can positively affect team innovation. However, few researchers have explored the relationship among the three, including CRM practices, team innovation, and team performance, how the three influence each other, and the mechanism of the CRM system. By dividing the influencing factors of CRM practices, this work builds the relationship model of CRM practices, team innovation, and team performance and investigates their influencing mechanisms.

Consequently, the main objectives of this work are to propose a conceptual framework exploring the relationship between CRM practices, team innovation, and team performance, the effect of CRM practices on team innovation, and the influences of team innovation on team performance. Specifically, this research clarifies the gaps in CRM practices that knowledge sharing will be replaced with information sharing (which many studies/authors) and the role of mediating the effect of team innovation on the relationship between CRM practices and team performance. A systematic review of the literature is appropriate to reinforce findings and identify research.

The study is organized as follows. Section 1 is about the introduction; after that, section 2 includes. We then present the conceptual framework based on theories and past studies. Finally, we suggest the research method in section 3, conclude this work, and propose further studies in section 4.

2 LITERATURE REVIEW

2.1 Theory applied in this study: OAM (Opportunity-Ability-Motivation) theory

Blumberg and Pringle (1982), Ölander and ThØgersen (1995), and Hughes (2007) proposed an integrative model that combines motivation (e.g., drives, wishes, urges or desires, emotion), opportunity (e.g., time, place, convenience, digital divide), and ability (e.g., knowledge, habit).

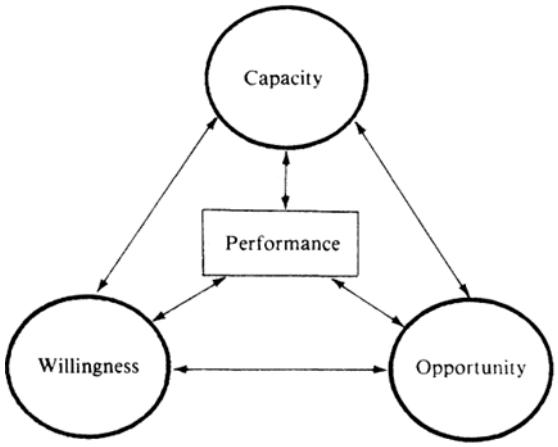

Fig. 1 – OMA framework. Source: Blumberg & Pringle (1982)

Maclnnis et al. (1991) defined opportunity as the level of distractions or limited time affecting consumers‘ intention. The opportunity component of OAM is similar to Ajzen’s concept of perceived behaviour control, which is a precondition for behaviour performance (Jackson, 2005). The preconditions are the management of time and place utility that influences consumer behaviour when an objective is a pro-environmental behaviour (e.g., recycling empty used cans) (Ölander & ThØgersen, 1995). Moreover, Hughes (2007) defined opportunity as the degree to which a customer believes that a digital tool exists to support actual behaviour in a system. The concept of ability is both knowledge and habit (Jackson, 2005). The customer’s knowledge received from a campaign sharing knowledge to change environmental behaviour. Knowledge is an essential consideration for product/service regarding pro-environmental conduct. Habits can be thought of as strategies designed to help customers learn green knowledge about products/services to form new green habits to reduce the cognitive effort associated with making decisions.

2.2 CRM and innovation definition

Definition of CRM

CRM is, first and foremost, a strategy and corporate philosophy that puts the customer at the centre of business operations to increase profits by improving customer acquisition and retention. It involves identifying high-value customers and automating processes to make sales, marketing, and service efforts more efficient and effective. In its complete form, CRM provides a 360-degree view of the customer and integrates all necessary information about the customer at every touchpoint – be it traditional voice, Internet-based, or wireless (Doshi, 2007). Hayley (2016) also mentioned that it is essential to clarify that CRM is not a technology in itself, but it utilizes technology to achieve its objectives. Technology makes it possible to integrate the large volumes of customer information required for CRM and efficiently transform it into valuable knowledge. Technology also enables a company to interact with its customers in ways that provide value to the customer and make it easier for the customer to do business with them. However, harnessing this customer knowledge to make better business decisions and being 'responsive to customers' remains the responsibility of individual managers and workers at all levels within the company.

Definition of Innovation

Today, innovation in an organization can develop breakthrough, new-to-the-world products or services that expand market opportunity and accelerate revenue growth for their organization as Kaminski (2011) has stated that the diffusion of innovation refers to the process that occurs as people adopt a new idea, product, practice, philosophy, and so on. Lundvall (2013) suggests that innovation as an interactive learning process should be the core of innovation study. In his words, "the closest we get to such a core in innovation studies is the conceptualization of innovation as an interactive process involving many actors and extending over time." Kline and Rosenberg (2010) define innovation as involving the creation and marketing of the new. These gauntlets, individually and in combination, make the outcome of the invention a highly uncertain process. Thus, a meaningful and helpful way to consider the process of innovation is as an exercise in management.

A study of Drach-Zahavy and Somech (2001) focused on innovation is defined as "the intentional introduction and application within a team, of ideas, processes, products or procedures new to the team, designed to significantly benefit the individual, the team, the organization, or wider society" (West & Wallace, 1991, p. 303). This definition emphasizes that innovation is related to intentional attempts of team members to arrive at anticipated benefits for the individual, the team, the organization, or the surrounding society, in contrast to top-down change. Furthermore, the definition applies to innovations across a variety of organizations: industrial and high technology as well as service and educational. Finally, the definition requires an application component, which will almost always imply a social element.

2.3 CRM practices and Team innovation

CRM practices refer to the different degrees of deployment and use of a CRM technology solution (Guerola-Navarro et al., 2021a). CRM practices establish a customer-centric information system and deploy direct marketing capability to the customer through CRM marketing programs (Tsou & Chen, 2019). Like any business management tool, CRM can be used to different degrees of intensity by its users, for other purposes, and in various areas of functionality. A starting point in the analysis of the conditions that lead to CRM producing a good outcome (CRM performance) is to have a way to establish the level of effective use of in companies, which is known as "CRM practices"(Guerola-Navarro et al., 2021b).

Recent studies have established different approaches for defining, measuring, and using the CRM degree of companies' use as a condition. Li et al. (2019) proposed a two-stage model for CRM value, with operational and strategic benefits and targeted firm performance, including an initial independent variable called the "CRM Usage" in their model. One of the main conclusions of Li et al. (2019) is that the operational and strategic benefits of CRM usage improve firm performance. In this case, as per performing quantitative analysis, CRM usage for a firm is calculated as the revenue-weighted average proportion of CRM use among all the firm's subsidiaries. In a very recent research model, Valmohammadi (2017) highlights the importance of the degree of use of CRM to measure its impact on business results.

Valmohammadi (2017) uses five elements for measuring the level of use that any company may have:

Information sharing. It is a central process by which team members collectively utilize their informational resources (Mesmer-Magnus & DeChurch, 2009). It refers to the sharing and exchange of available information, including market demand, customer preferences, sales promotion, and the introduction of new products through interactive activities between companies and their customers (McEvily & Marcus, 2005).

Customer involvement. It refers to how the customer plays a role in product development and the extent of its participation in new product development (NPD) activities, technical meetings, annual supply chain conferences, and market evaluation conferences. (Laage-Hellman et al., 2014).

Long-term partnership. It refers to a philosophy of trust and cooperation enabling better understanding, creation, and delivery of value (Anderson et al., 2008). It is a business relationship with trust and commitment between two firms. Both firms must share similar goals and pursue mutual profits on a reliable and reliable basis (Mohr & Spekman, 1994).

Joint problem solving. It is understood as the degree to which actors share responsibility for maintaining actors' relationships and for issues that arise (Heide & Miner, 1992). It refers to the collaboration between actors (e.g., companies, customers) in solving problems together and the exchange share responsibilities when they face issues (McEvily & Marcus, 2005).

Technology-based CRM. It includes digital technologies including data storage, data mining, and CRM software systems to support CRM processes offering assistance to customers (Sin et al., 2005).

These five elements provide a clear picture of how much companies use CRM tool capabilities (Valmohammadi, 2017). However, it is necessary to distinguish between information and knowledge because the difference between the two concepts is not always clear. While knowledge answers the questions (e.g., why, how), which is helpful for the decision-making and may benefit a customer or a firm, information answers other questions (e.g., who, when, what, where), and it has meaning for a user (Elearn, 2013). Consequently, knowledge sharing is more challenging than information sharing because the specialization of each functional area renders organizational knowledge situational, cultural, and contextual (Boland Jr & Tenkasi, 1995).

Thus, our study will focus on knowledge sharing as an essential factor of CRM practice. Knowledge sharing is an interaction through which knowledge is exchanged among people, between consumers and businesses, or within or between organizations (Bukowitz & Williams, 1999; Ipe, 2003; Serban & Luan, 2002). Knowledge sharing has been identified as the key performance indicator of businesses.

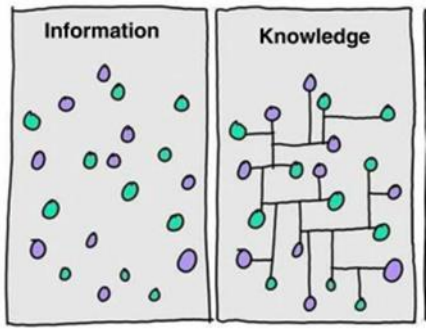

Fig. 2 – The difference between information and knowledge. Source: Ponting (2017)

This study focuses on the five most CRM practices considered: knowledge sharing, long-term partnership, customer participation, joint problem-solving, and technology-based CRM. Researchers (De Dreu & West, 2001) assessed innovation as a function of minority dissent and participation by examining through interviews with the team supervisors. The research assistants explained that the purpose of the discussion was to obtain additional insight into the team's functioning. The supervisors were asked to describe as many innovations as possible. The interviewers stimulated the supervisors to think about innovations by giving them some examples and then asking them to explain the team's innovations in detail. These descriptions allowed to double-check whether innovation indeed matched the definition of innovation (i.e., a novel procedure, method, product, or service that the team implemented to improve its work) and discouraged supervisors from making up innovations.

From the above definitions, team innovation can be understood as "a team's capability to generate novel and original ideas (i.e., creativity) as well as the capability to put these ideas into practice such that they yield beneficial outcomes (i.e., implementation)" (Zacher & Rosing, 2015, p. 56). According to van Knippenberg (2017), team innovation is important in organizational psychology, behaviour, and practice. The author's review identifies two main perspectives in team innovation research, the knowledge integration perspective and the team climate perspective. It also identifies the contingencies of the relationship between idea development and idea implementation as the essential understudied issue in team innovation research.

According to the OAM framework, CRM is a process in which team members continuously claim customer-relationship identities while their customers are willing to recognize and accept their partner roles. In line with the OAM framework, CRM practices involve team members building a relationship and facilitating an environment for customers to take on innovation roles through CRM practices that enhance their opportunity, ability, and motivation to participate in innovation within teams' companies. For example, CRM practices pursue extensive knowledge sharing, creating better opportunities to provide customers with diverse knowledge and skills to lead themselves and others and develop novel ideas in a team.

Existing research on CRM presents the importance of innovation, involvement, teamwork, and focus on results to build up a corporative culture oriented towards CRM (Iglesias et al., 2011), and also the important role that collaboration between customers and employees plays in the construction of long-term relationships with customers (Lourenço & Sette, 2013). More recent research has been analysing: how CRM systems contribute to innovative approaches to a relationship that impact building relationships with customers (Lendel & Varmus, 2015). Thus, we hypothesize the following.

Hypothesis 1: CRM practices are positively related to team creativity/innovation.

2.4 Team innovation and team performance

A study by Drach-Zahavy and Somech (2001) focused on team innovation: "the intentional introduction and application within a team, of ideas, processes, products or procedures new to the team, designed to significantly benefit the individual, the team, the organization, or wider society" (West & Wallace, 1991, p. 303). This definition emphasizes that innovation is related to intentional attempts of team members to arrive at anticipated benefits for the individual, the team, the organization, or the surrounding society, in contrast to top-down change. Furthermore, the definition applies to innovations across various organizations: industrial and high technology and service and education. Finally, the definition requires an application component, almost always implying a social element. According to van Knippenberg (2017), team innovation is important in organizational psychology, behaviour, and practice. The author's review identifies two main perspectives in team innovation research, the knowledge integration perspective and the team climate perspective. It also identifies the contingencies of the relationship between idea development and idea implementation as the essential understudied issue in team innovation research. The authors (Ali et al., 2020) wrote that team innovation performance describes how team members can change available products or processes or develop new ones using internal and external knowledge. These authors also agree that knowledge is a distributed asset, and innovation is highly collaborative. When a team encounters a problem with no available solution, it innovates through ideas and knowledge sharing and building on one another's work. In such situations, team members can also explore and assimilate external knowledge from outside team boundaries to adopt new ideas and solutions to problems that have been solved elsewhere, thus making a positive contribution to team innovation performance.

Team performance is defined as how a team accomplishes its goals or mission objectives (Devine & Philips, 2001). Specifically, team performance is the degree of satisfying pre-set criteria such as quality, cost, and completion time (Hoegl et al., 2001). Better team performance is expected to result from teams consisting of members with diverse task knowledge (Wei & Wu, 2013). Team performance is focused on the execution of activities related to collective goals (Salas et al., 2015). Edmondson shows that psychological safety is an important mechanism that influences behaviour and performance outcomes in terms of efficiency in teams. Edmondson defines team psychological safety as a shared belief that the team is safe for interpersonal risk-taking. Learning improves in a team where members trust each other, dare to seek help, ask questions, and tolerate mistakes (Gustavsson, 2021). Team performance is conceptualized as a multi-level process (and not a product) arising as team members engage in managing their individual- and team-level taskwork and teamwork processes (Kozlowski & Klein, 2000). Conceptually, teamwork is nested within team performance and is a set of interrelated cognitions, attitudes, and behaviours contributing to the dynamic processes of performance (Salas et al., 2008). The definitions of performance and effectiveness on the team level closely parallel these terms on the individual level. Performance is the activities engaged in while completing a task, and effectiveness involves an appraisal of the outcomes of that activity (Fitts & Posner, 1967).

Based on the OAM theory, the theory argues that team performance is best served by a CRM that contributes to team performance of collaboration between customers and employees by increasing their providing opportunities to perform (O), abilities (A), and creating motivational incentives (M) (Boselie et al., 2005). Team performance is influenced by various factors, including teamwork engagement at a team level and work engagement at an individual level (Rahmadani et al., 2020), team proactivity, and proficiency (Liu et al., 2020). As far as team-oriented CRM practices are concerned, this implies that CRM practices should be aimed at developing team performance by investing in team innovation as mediating factor. Cohen and

Bailey (1997) argue that team innovation refers to a team using some viewpoints, processes, or methods that have new ideas and improve team performance. Thus, in line with theory and previous studies, we propose to hypothesize the following:

Hypothesis 2: Team innovation mediates the relationship between CRM and team performance.

Fig. 3 – Conceptual framework. Source: own research

3 METHODOLOGY

After defining the research problems in section 1, we performed a literature review of previous research to identify papers that could be relevant to shape hypotheses to solve the research problems in section 2. To the best of our knowledge, no publications are available in the literature investigating the applicability of the OAM theory in the aviation domain for customer relationship-building purposes.

A systemic search methodology is used to address the preliminary research problem to answer the mentioned purposes. A quantitative approach should be applied to our hypotheses. The collected research data will be analysed and interpreted. We will conduct the survey study and questionnaire technique due to this research to use and test the relationship among variables (Saunders et al., 2009). Participants are those who work in aviation and tourism in Vietnam and have at least one working experience year.

We will develop a questionnaire survey to collect data. The original questionnaire was developed in English on the constructs and items of our studies. The sample size should be more than ten times the most significant number of structural paths directed at a particular construct in the structural model (Hair Jr. et al., 2014). Thus, the sample size of 200 is consistent with this study.

Concerning data analysis, SMART-PLS software is applied first to assess internal consistency reliability, convergent validity, discriminant validity of the measurement, correlation matrix, structure model, and test hypotheses. Then, the process model is utilized to study the interactive effects of CRM practices, team innovation, and team performance. The study relied on journal articles and other relevant publications obtained from Scopus and Web of Science databases. We searched customer relationship management (CRM), CRM practices, team innovation, and team performance. Second, we included studies focused on CRM practices, team innovation, and team performance-related concepts. Based on the aforementioned criteria, the publications were relevant and suitable for the present study.

4 EXPECTED RESULTS AND DISCUSSION

The results will supply a theoretical framework to evaluate team performance. A literary study will provide a comprehensive knowledge framework on CRM practices and team innovation toward team performance. Learning outcomes such as the concept of team performance and defining individual factors can serve as teaching material for the subject of CRM for both full-time study and combined forms of study.

Another benefit could be the development of a customer relationship-building methodology. Authentication of the customer relationship model for teamwork will contribute to the

illumination of the issue. The work may serve as a document for training activities for companies. The new approaches can see the benefits of research for social practice. The analysis results may serve to increase the team performance of Vietnamese companies. Another level may be to strengthen the team innovation potential of companies. The authors propose a framework for creating integrated CRM and team innovation. Our approach is based on the OAM theory suitable for developing a reference framework for a Vietnam company. We aim to explore the applicability of OAM theory for implementing a customer relationship management program within the aviation domain. Based on the literature review approach, we will propose a CRM framework through which a Vietnam company can implement a CRM program using the OAM theory.

5 CONCLUSION

The main objective of our study is to propose a conceptual framework to explore (1) the critical role of knowledge sharing in CRM through the customer-centred approach of modern marketing approaches (2) the direct effects of CRM practices (knowledge sharing, customer participation, long-term partnership, joint problem solving, technology-based CRM) on team innovation and (2) mediating effect of team innovation on the relationship between CRM practices-team performance.

The systematic literature review is appropriate to consolidate the research findings and identify the research gaps. For the contribution of the literature, we could consider testing hypotheses as a proposed framework to determine the relationship between CRM practices, team innovation, and team performance. In practice, managers or leaders should inspire or create an innovation environment that retains team innovation and team performance.

In conclusion, published studies play an essential role in specifying the relationship between CRM practices, team innovation, and team performance. The conceptual model also suggests some studies in the future to explore teamwork engagements and team learning which can directly impact team efficiency and performance. Further studies in the aviation and tourism context should evaluate this conceptual framework by employing qualitative research and testing the above hypotheses through a quantitative research in the Vietnamese industry. This research work contributes to the existing literature in extending OAM theory to investigate (1) the CRM practices-team performance relationship and (2) the theory to explore the mediating effect of team innovation that gives a theoretical suggestion to scholars working in tourism as well as in aviation management.

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THE USE OF INDUSTRIAL ENGINEERING METHODS IN CONJUNCTION WITH DIGITIZATION IN PROCESS IMPROVEMENT

Martin Mareček-Kolibiský, Lukáš Závodný

Abstract

By applying technologies and principles of digitization, industrial practice also requires a more consistent application of methodologies, methods, and tools for improving the quality of processes, products, services, etc. The implementation of digitization concerns, more or less, all areas of industry, public administration, healthcare, and all areas of life. We perceive the most significant implementation of digitization in the automotive industry, the engineering industry and the electrotechnical industry. The main goal of the paper is to analyse and use methods of industrial engineering in industrial practice and to identify potential relationships between methodologies of industrial engineering and digitization. The paper focuses on the use of improvement methodologies, specifically deals with the Lean Six Sigma methodology in the context of digitization. In this paper, we are based on the results of using the methods of industrial engineering in industrial practice. The results come from a questionnaire survey, which was conducted as part of the dissertation project. As high-quality requirements are inevitable, as competition grows, and every business wants to be competitive and grow. Various improvement methodologies must help companies in development, which companies should use and analyse faulty processes and deficiencies in products. This growing competition in the market logically also increases the requirements of customers today. From the questionnaire survey that we had available, we dealt with data on the use of methodologies and methods of industrial engineering in companies to improve processes, we also looked at the data obtained on how digitalization affects the company. Digitization and other new technologies The development of the company and the methodology of improvement serve as a tool according to which companies can apply individual methods and tools for the improvement of individual activities, processes, products, etc. in industrial practice.

Keywords: *digitization, improvement methodology, Lean Six Sigma, industrial engineering*

1 INTRODUCTION

We are currently living in a period of crisis (pandemic) and at the same time, there is a transformation of industry, society, and other areas of life into the digital environment. All these events indicate that competition, customer acquisition and a certain market space is a major challenge (for example the quality and price of the products and services offered). This combination of given crisis and the transformation of society into digital creates uncertainty in people and in the business sphere, and it is a challenge for everyone involved. At the same time, the challenge of "fighting" for a customer, improving competitive advantage, reducing costs, speeding up and making processes more efficient etc., is extremely important for a company to respond to technological possibilities, because every industrial revolution provides new technologies that cause a change in people's lives and the functioning of processes. It is to this fact that digitization, as well as the use of various methods of improvement, should help. As research and practice shows the most effective methodologies for leading and implementing activities, respectively. Process improvement projects are Six Sigma and Lean thinking.

We know a large number of methodologies and methods of industrial engineering aimed at improving processes and innovation, but it is the combination of Six Sigma and Lean thinking

that should help to significantly improve business practice. Businesses speak for themselves and present that they are improving their processes. Since the aim of the paper is to analyse and use methods of industrial engineering in industrial practice. We want to find out the real state of use of methodologies and methods of industrial engineering in industrial practice, in order to improve processes, increase quality and eliminate shortcomings. We focused on identifying questions about how, using which methodology or methods of industrial engineering, companies improve their processes and how digitization is perceived in industrial practice. Using a questionnaire survey, we found out and we want to point out the real state of use of methodologies and methods of industrial engineering in practice.

Lean and Six Sigma are mainly used in the analysis and subsequent optimization of physical and organizational flows. According to an empirical rule that 50% improvement in business processes can be achieved without digitization, while the remaining 50% improvement in processes is linked to digitization and is dependent on information systems and networks (Nicoletti, 2006).

2 THEORETICAL BACKGROUND

Companies in the Czech Republic do not use the full potential of Lean management. Based on studies by the World Economic Forum from 2019, the Czech Republic was in 32nd place in competitiveness and it is placed regularly between 30th and 35th position (Schwab, 2017). Slovakia's competitiveness is at a lower level then Czech Republic, in 2019 was Slovakia in 42nd place. and of the countries of Central Europe, only Hungary took place behind Slovakia (Schwab, 2019). Compared to previous years, Slovakia's position has improved, in 2017 the country was in 59th place behind countries such as Rwanda (Schwab, 2017).

The absence of Lean management is not only a specialty of the Czech Republic and Slovakia, it is a worldwide problem, e.g. in Germany, which ranked 7th in the competitiveness index, Lean management is fully utilized only in 7% of companies (Schwab, 2017; Schwab, 2019).

The Czech Republic is lagging in innovation and implementation of new systems into already established processes, and the situation is unsustainable in the long run. Companies focus on reducing production costs and labour, are afraid of change and fundamental decisions, and lack systematicity and standardization. Companies that have established Lean management focus on standardization, innovation of products, processes and technologies, along with reducing costs and increasing labour productivity.

Each crisis changes market requirements (Birkie, 2015). It is important for companies to be flexible and adapt quickly to requirements. Companies that have experienced the Lean philosophy are becoming more competitive, and in times of crisis, the imaginary scissors between companies with established Lean management and companies without it open even more, and this can mean the difference between staying on the market and bankruptcy.

The goals of digitization are to change industry and other areas of life to become simpler, more efficient and "smarter". Technologies such as the Internet of Things can collect and share data directly with other devices through a cloud environment that provides a vast amount of information that is collected and stored on analysed data-analytics repositories. Digitization brings several benefits, such as the monitoring of key indicators in real time and thus the ability to respond immediately to the current situation. Another benefit is the automatic processing of reports and an overall overview of everything in the company, which is usable for everyone from production workers to executives. If the company has more branches, it will be possible to compare individual results with each other (Metternich, 2016).

Implementing Lean management takes time, because it is a big intervention in the corporate culture, as well as with digitization. Businesses that are forced to digitize their processes immediately, e.g. in times of pandemic, they do not have enough information about the tools and methods used to do so and there is room for error. For process digitization, it is important to define the requirements and what the company wants to achieve with digitization. Additional redesign of systems is time and money consuming. Another risk is the lack of understanding of the system by employees and the non-use of the full potential of digitization or any new methods introduced in a fast time sequence. If the company has its own developers, it runs the risk that the newly created programs and systems will not be compatible with other applications in the future, or with other departments in the company, which in a larger time will mean switching to another system or modifying the existing system, if necessary. However, it will be possible. Technologies are constantly evolving, and the interoperability of all systems is extremely important for correct and efficient data processing (Hofmann & Rusch, 2017, 23-34).

Lean management is constantly evolving and with the approach of new technologies and industry 4.0, these methods are offered to combine and interconnect. In general, companies that have experience with the introduction of new methods and have a continuous process of improvement intuitively resort to digitization as a next step. Continuous improvement is a cyclical process examining existing activities and processes that need to be identified and subsequently improved. Almost every medium and large manufacturer should have a methodology of improvement (e.g., methodology based on ISO 9004, Six Sigma, Lean management), currently the combination of Lean and Six Sigma methodologies, i.e. Lean Six Sigma, is coming to the forefront in the world (Spath, 2013; Wan et al., 2015).

Digitization of Lean management has a positive impact on production processes both in terms of improving existing technologies and the possibility of creating new technological possibilities and systems. The potential in the integration of lean manufacturing and industry 4.0, specifically Lean Six Sigma, has been explored in its applications to accelerate the process of extracting key knowledge from Big Data and how data processing can help innovate and shed new light on projects requiring Lean Six Sigma (Sanders et al., 2016; Fogarty, 2015; Arcidiacono et al., 2016).

Lean and Six Sigma are a combination of two problem-solving methodologies. In both cases, the people who implement the methodologies apply the kaizen method. The team examines the process involved in identifying and implementing improvements. Simply put, leanness usually begins with an understanding of the added value for the customer and a detailed examination of the process using value stream mapping (VSM). Improvements include either eliminating waste, improving process quality, or incorporating newer technologies that did not exist in the process. Six Sigma provides analysis management to define and quantify error types. Statistical analysis is used to identify the root causes of defects (Arcidiacono et al., 2012).

By introducing Industry 4.0 and digitization into business practice, new, future processes will be created. They will contain more technology and will be smarter, but they will remain processes. These processes will still create space for the use of Six Sigma. These processes will continue to require analysis, the definition of capabilities, control to be effective, but they will also require information and the definition of additional and new parameters that will affect them. With increasing automation and the potential to mass-produce unique products, automation processes should collect more data faster and in real time. There will be a large flood of data and information about processes, which will need to be sorted according to the importance of the parameters at a given time (Reinsel et al., 2018; Pugna et al., 2016). The new parameters will be measured by built-in sensors on machines, equipment, examples of parameters are temperature, speed, pressure, rotation, etc. This is precisely the space for the

development of the Six Sigma methodology, which could develop this amount of data and information and analyse this data in the repository. Thanks to the area of Industry 4.0, such as Big Data, methods and methodologies will be developed, the basis of which is measurement, analysis and statistical tools and techniques. Current statistical tools and techniques will increasingly find their use, and it is likely that new techniques and tools will emerge aimed at statistical management and quality control of new processes. New tools and methods will emerge, but current methods such as DMAIC, PDCA cycle, Pareto analysis or Ishikawa diagram will still be used, most of the methods and tools used in the Six Sigma methodology will continue to be used, it will still be necessary to understand the causes of problems and solve existing problems. Future machines and equipment will take control of the processes, individually or in cooperation with statistical control, real-time analyses, auto-corrections, etc. (Gijo & Scaria, 2014).

Businesses that have started implementing elements and technologies of digitization and Industry 4.0 have experienced the rapid development of access to data from production processes and the connection of physical processes with the digital environment, all thanks to elements and technologies of digitization such as sensors, various cloud solutions, artificial intelligence, the Internet of Things and more (Bocciarelli et al., 2012). As a result, the increased use of Big Data through this production data and its analysis leads to effective management of business strategies and the creation of decisions that are reliable and based on data and facts. It is the specialists with knowledge and experience in the use of Lean Six Sigma methodology that will ensure meaningful integration of new technologies into companies and will be able to properly analyse and research data within Big Data to provide useful information to ensure business improvement and thus better position. within the framework of competitiveness, cost savings, eliminates waste, work more efficiently, etc. (Fogarty, 2015). These Lean Six Sigma experts know where and how to collect data, analyse, and interpret raw data in business practice. Their role will not change due to the large amount of data available, on the contrary, their skills and experience will be needed to a greater extent, as they are able to guide decision-making with the right data (Bocciarelli et al., 2012).

The Lean Six Sigma methodology as an integration of the Lean management and Six Sigma methodologies focuses on the variability of processes and their optimization through the Six Sigma methodology and standardization, resp. streamlining production and eliminating waste using the Lean management approach (Arcidiacono et al., 2012). The Lean Six Sigma methodology has proved its worth in various industries, so its application is not limited to the manufacturing sector and is also applicable to the service and government sectors. Previous research has examined the applicability of Lean Six Sigma under the Big Data tool to speed up key data selection. The potential use of Lean Six Sigma was identified, but the selection of key data using Lean Six Sigma was not fully concluded (Fogarty, 2015; Rother, 2017).

With the arrival of digitalization and new data collection technologies, companies have begun to educate their employees on the use of Lean Six Sigma. Due to the large amount of data in all areas of business practice and increased competition, high quality requirements, it is essential that the company uses only the data that are necessary to improve the activity, respectively the processes. With the arrival of digitalization and automation, processes in companies will have to be even better than before, managers are also aware of this fact. Managers and employees who have knowledge of continuous process improvement and experience in the use of Lean Six Sigma will play an active role in ensuring the meaningful and functional integration of new technologies into the company's operations. Lean Six Sigma projects also follow the Six Sigma DMAIC logic process. It is thus a classic cyclic process in the logical arrangement of steps to define, measure, analyse, improve, and control. This procedure can solve any kind of problem (Arcidiacono & Pieroni, 2018).

Data collected using digital technologies will provide businesses with information that they can use to streamline business operations. This can be, for example, information to help supply chain managers find out where a truck transporting material is, and they can also have information on the actual amount of stock in the warehouse and its location. This will be information providing details of each stage of the process in the company (Iazeolla & Pieroni, 2014).

Using this information, if there are problems in the processes, the goal of Lean Six Sigma is to find out where the process has shortcomings, what changes need to be made to improve the condition, or complete elimination of the error. This is to be helped by the harmonization of digitization and Lean Six Sigma, so that the company can respond to the problem in real time and minimize losses, streamline operations, provide better products, and provide quality services to the customer (Sodhi & Singh, 2013; Gijo & Antony, 2014).

Industry 4.0 and digitization with their technologies significantly affect the production and non-production environment in the company. These business processes and the entire business environment will undergo radical changes in the implementation of Industry 4.0 technology and digitization. These technologies provide planning, data, control in real time. Industry 4.0 and digitization therefore help speed up data collection and eliminate the human factor that can make mistakes in data collection. The main purpose of Lean Six Sigma is, based on the collection of data from Industry 4.0 technology, based on predictive analysis. Currently, most companies use descriptive analysis (control charts, averages, mean values, etc.). This analysis is useful, but for Industry 4.0 it is not as useful as predictive analysis, which allows to know or predict what will happen, it is possible to know in advance the causes and consequences of problems, so predictive analysis predicts the future using the data (Arcidiacono & Pieroni, 2018; Morabito, 2015).

3 METHODOLOGY

To fulfil the main goal of this paper defined by us: analysis and use of industrial engineering methods in industrial practice. We used several questions from the questionnaire survey, which is solved within the solution of the dissertation of the author Martin Mareček-Kolibiský. The work deals with the use of industrial engineering methods in improving production processes in industrial practice. In the article we present some results obtained in the survey. We chose this form of communication with companies due to the pandemic situation that was taking place in the Slovak Republic. The survey was conducted in the form of a questionnaire in electronic form. The questionnaire survey was distributed via an e-mail database via e-mail. In the accompanying e-mails to the questionnaire, we explicitly asked the respondents to send the questionnaire if they do not work with methods of industrial engineering for process improvement, to forward the questionnaire survey to a worker who works with methodologies and methods of industrial engineering for process improvement. 142 companies were contacted; we focused only on medium and large industrial companies according to the number of employees. The questionnaire was mostly closed questions or closed questions with the option "other". From the total number of 11 questions we have, from the questionnaire we used 4 questions for our contribution, which are thematically related to our intention to work. The results of the questionnaire survey were evaluated graphically using pie charts, bar charts using simpler statistical methods. The survey was attended by 64 companies, of which 68.75% of companies from medium-sized enterprises (50 - 249 employees) and 31.25% of companies from large enterprises (over 250 employees). We also structured companies according to the nature of production into piece, serial, and mass production. The figure (Fig. 1) graphically shows the percentage of enterprises according to the nature of production, so that we know what

representation in our survey and the nature of production with respect to the use of digitization. It is likely that enterprises of serial and mass production use more elements and technologies of digitization than enterprises of smaller size and with the nature of production defined as piece production.

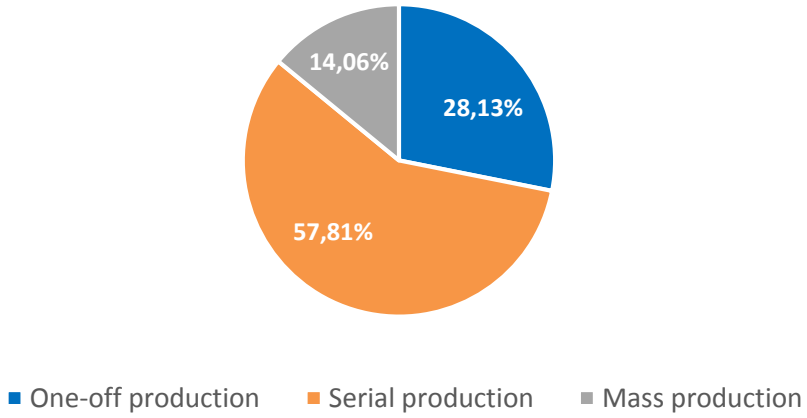

Fig. 1 – Production types of surveyed companies. Source: own research

4 RESULTS

As part of the solution of the VEGA project and the solution of the dissertation, our intention was to find out the current state of application of improvement methodologies in industrial practice in Slovakia. With the question from the survey "Which methodology of production processes is most often applied in your company?", We wanted to achieve a realistic finding out which methodologies are most often used in industrial companies in Slovakia. Respondents had a choice of seven options: Lean Management, Methodology according to ISO 9004, Lean Six Sigma, Kaizen, Six Sigma, Reengineering and others. If possible, other respondents gave the following answers: no methodology in place, own system, empirical experience, ISO 9001, I cannot name the methodology, 5S, Risk analysis, combination (Lean Six Sigma, 5S, ISO 9004). In this question, we can also consider the possibility that the respondents who filled out the questionnaire do not have sufficient knowledge in the issue, as the answers they provided (in the grey bar graph) were not methodology but methods or analyses.

The graph (Fig. 2) shows the percentages. The graph is divided by the colours blue and grey. The percentage of answers marked in blue are the methodologies from which the respondents had a choice, and the second part of the bar graph marked in grey are the answers given by the respondents in the survey. The most frequently used methodology is the Lean Management methodology (18.8%), followed by the ISO 9004 Methodology (12.5%) and the third most frequently used methodology is Lean Six Sigma (10.9%). The negative finding is the fact that up to 15.6% of respondents stated that no methodology is in place in their company, which is surprising, as these companies may have major problems in the future in securing digitization, in the fight for the customer, in maintaining a competitive benefits, etc.

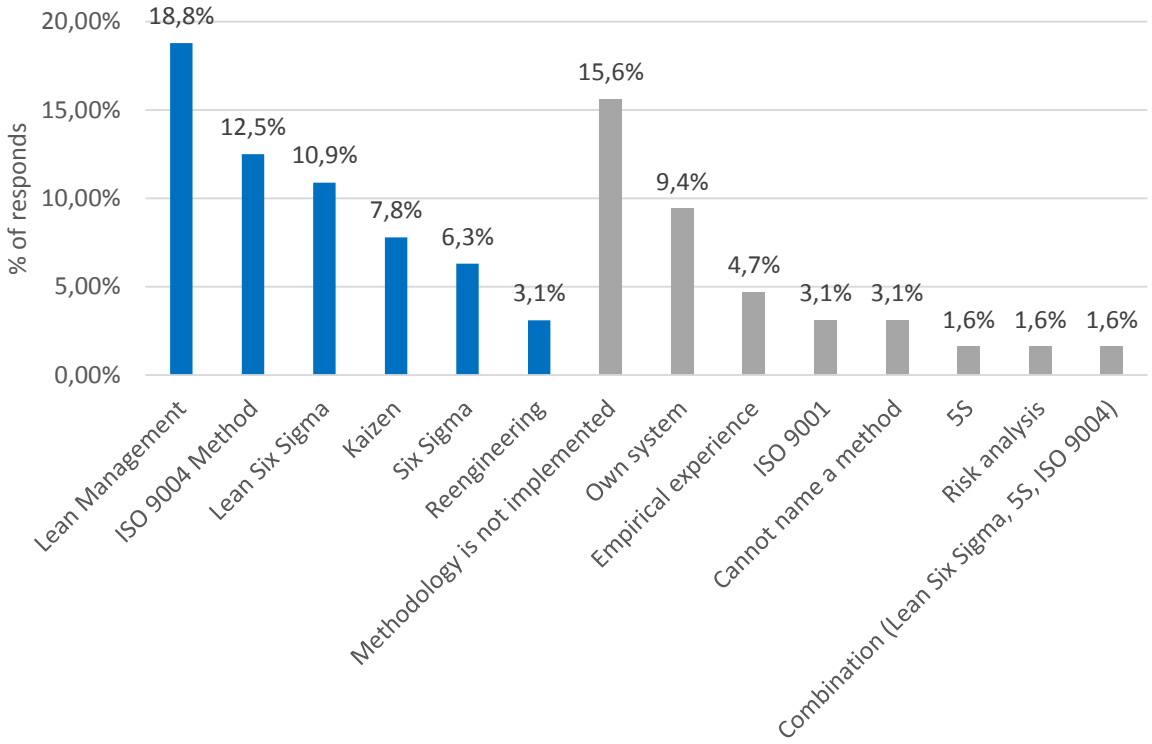

Fig. 2 – Application of improvement methodology in industrial companies. Source: own research

This answer was provided by the companies, which stated as the nature of production the serial, mass and one-off nature of production. As many as 71.4% of respondents who gave the answer to Lean Six Sigma stated the nature of production as series production. This assumption was to be expected, as it is in series production that waste is eliminated the most, process time is reduced, and so on. It is also the most represented nature of production in a given survey.

Another question that we selected from the survey and evaluated in the article is the question "How does digitalization contribute to the improvement of processes in your company?". Through this question, we found out how digitization contributes to the company's activities. Respondents had a choice of positive, negative, neutral and not using. Within these answers, they were able to state in what specific way digitization contributes positively and negatively.

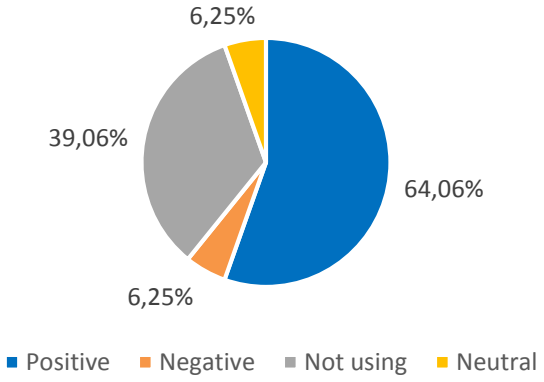

Fig. 3 – Impact of digitalization. Source: own research

The results of the evaluation of the question are shown in the graph (Fig. 3). The majority of respondents (64.06%) mentioned the possibility of a positive impact of digitization on business activities. Specific positive impact responses were process acceleration, production automation,

real-time monitoring, an innovative approach, increased productivity, increased quality, and a reduction in the negative effects of the human factor. Among the negative effects were the following answers: lack of qualified employees and economic burden for the company, only 6.25% of respondents opted for this option. An equal share of responses was seen as a neutral impact of digitization. Respondents also chose the option of not using digitization in the company, up to 39.06% of respondents, which in our opinion is a high percentage of responses in the survey. Some respondents in the question stated that digitization has both positive advantages and negative disadvantages.

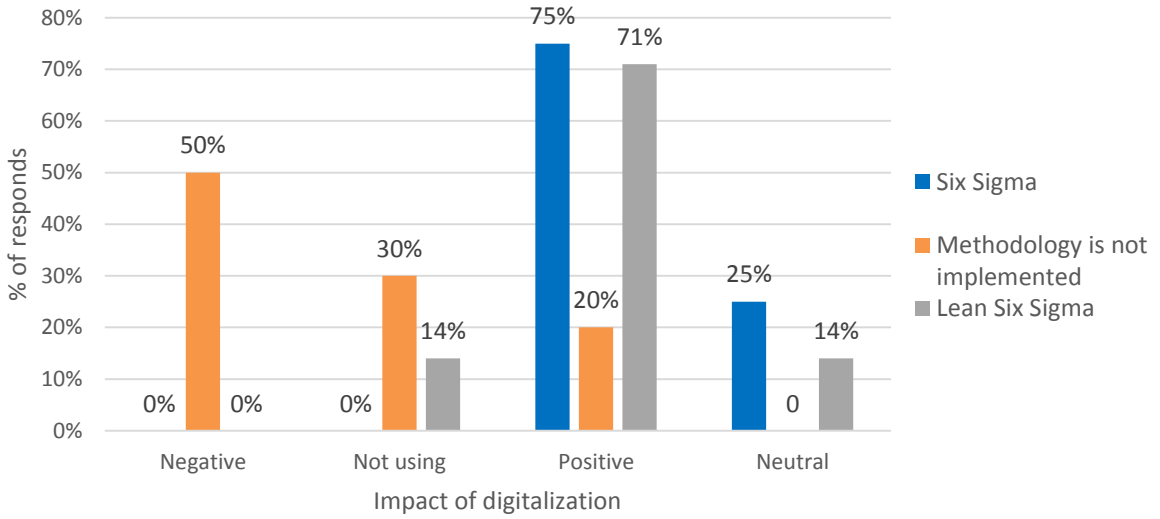

Fig. 4 – Comparison of methodology and Impact of digitalization. Source: own research

In this survey, we compared the impact of digitization with respect to companies that use the Six Sigma and Lean Six Sigma methodologies and companies that do not have any improvement methodologies in place. The results show (Fig.4) that companies that do not have any methodology in place are much more affected by the negative factor of digitization of up to 50%. On the contrary, companies that use Six Sigma stated that they perceive the positive impact of digitization 75% and with Lean Six Sigma 71% the share of positive response. In view of these new findings, we can say that the use of improvement methodologies also has an impact on the future of the introduction of digitization and Industry 4.0.

There may be several reasons why companies have answered the benefits of digitization in the negative. In practice, it happens that employees are worried about their jobs because they are afraid that the system may replace them. Another common reason is insufficient training of employees in implementation and digitization, so it is not possible to use all functions and employees see it as a burden rather than as an aid. If the implementation of digitization in companies is in a hurry, is not sufficiently communicated or the implementation is clearly poorly implemented, it may happen that employees are sceptical of further changes in the process after this negative experience.

The last area examined was the expectations of companies regarding digitization and Industry 4.0 within the quality management. Due to the nature of the question, this question was an open question and as many as 53.13% of respondents stated that they had no expectations. Given that the survey was filled in by employees in middle and senior management positions who work with the methodologies, implement them, and have information on digitization and Industry 4.0 technologies, the finding was surprising. Managers should be able to define expectations and goals with respect to the implementation of digitization and should have a vision. Given the expectations and goals of the future state, it is possible to retrospectively analyse the

implementation of digitization within the company. Respondents' answers are shown graphically in Fig. 5.

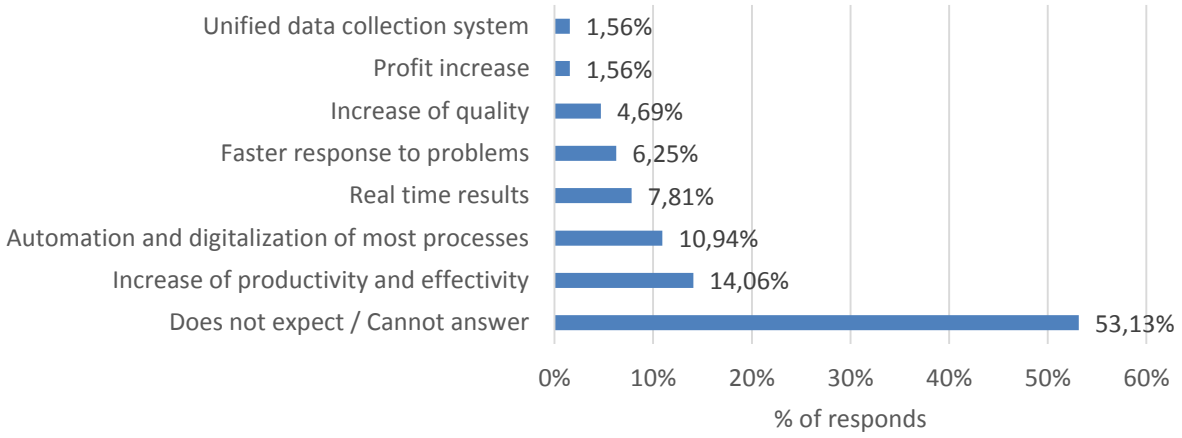

Fig. 5 – Expectations from digitization and Industry 4.0 within the quality management. Source: own research

These were the following answers: increased productivity and efficiency, automation and digitization of processes, real-time parameters, faster responses to problems, increased quality, increased profits, a unified data collection system.

5 DISCUSSION

Based on the conducted questionnaire surveys, it is possible to follow that in most cases, only methods and tools of industrial engineering and quality management are applied in companies in Slovakia. These are methods that in most honeys focus on the issue of slimming and the use of simple methods of industrial engineering (5S, basic tools of quality management, etc.). When it comes to applying improvement methodologies, most companies apply Lean Management, or do not have any methodology in place. Six Sigma, which are based on statistical methods and reduction of variability. It is the Six Sigma methodology that contains advanced methods of industrial engineering, which in a more significant honey contribute to the continuous improvement of processes in companies. With these methods, we can achieve proactive problem solving and proactive proposals for action. The impact and introduction of digitization into business practice will be further guided by the improvement of proactive improvement. Only at present, some companies do not have an established methodology of improvement at all, which will have existential problems for the whole company in the future.

6 CONCLUSION

In recent years, technology and technological progress have grown exponentially. Humanity, science and industry use technologies that make everyday life easier. Technological progress is advancing and what we do not know today can be known and used tomorrow. This is also the case in industry and the use of elements and technology of digitization, which has a positive impact on businesses.

The aim of our research was to analyse and use the methods of industrial engineering in industrial practice and to identify potential relationships between methodologies of industrial engineering and digitization. Through our questionnaire survey and subsequent evaluation of selected questions, we found a negative state of use of methodologies in industrial practice, as

respondents with companies also mentioned individual methods of industrial engineering instead of improvement methodologies.

From the answers in Figure 5 more than half of the respondents cannot name or imagine what benefits digitization can bring, and this is directly related to the fact that most companies do not know about digitization but know about it but is not a strategically important topic for them, whether they have established digitization but do not understand it. For the development of Czech and Slovak companies, it is essential that they begin to perceive the benefits of implementing digitization and industry 4.0, because other countries use the potential and the difference between these countries will be greater every year and month and such differences are very difficult to catch up.

The concept of digitization and Industry 4.0 is increasingly being implemented in companies. Due to our research linking digitization with industrial engineering methods, we focused on the Lean Six Sigma methodology, which has great potential in the future in application in industrial practice, is applicable in industry, but also in services, healthcare and other areas. It is the application of the Lean Six Sigma methodology that will ensure the continuous improvement of all processes using the latest technologies. Top management plays a key role here and all employees must be involved in these activities.

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AUTOMATION AND ARTIFICIAL INTELLIGENCE IN LOGISTICS – POTENTIALS AND FIELDS OF APPLICATION

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Abstract

Automation of processes in combination with artificial intelligence (AI) and Big Data are promise potential that disclose new applications in logistics. Especially for automation in general and Robotic Process Automation (RAP) in particular, the comprehensive potential in process management, production and services in the economy have long not been exhausted. Concrete automation potential, especially in the logistic context, to identify, should be the subject of this paper. As the main objectives, the structure and functional methods of automation as well as artificial intelligence are shown and possible potentials are determined. Based on this, the present article illuminates the concrete applications of the RAP as a cost-effective alternative to AI. Furthermore, recommendations for action are given for the implementation and use of AI or RAP systems. On the secondary research explicitly, current, thematically relevant, sorted by application areas, various articles from the leading journals of the industry as well as publications of the largest system houses worldwide has been evaluated systematically on theoretical foundations for the reporting of this Article reviewed and above all structured. Restrictions on the research exist with regard to specific applications of artificial intelligence. Thus, concrete application examples are not the subject of the article. A critical assessment as well as recommendations for action and a guideline to check the feasibility conclude the versions. From the findings, further research needs will slide, especially in relation to ethical questions related to AI.

Keywords: *Automation, robotic process automation, AI in logistics, machine learning*

1 INTRODUCTION

The steadily growing interest in the methods of artificial intelligence and in particular machine learning in the field of logistics will essentially depend on the extent to which the application potential of such technologies can be identified. Automation in connection with AI and its sub-categories are a strategic economic factor in economic terms on a global level - identifying potential in this regard is a challenge for companies. In the future, the competitive strength of a company will depend heavily on how and to what extent a certain class of processes (machine learning, which generates knowledge from experience) can be used and implemented. The automation of various processes in logistics is therefore increasingly taking place with the help of artificial intelligence. Compared to other industries, such as marketing, the use of AI in logistics, specifically in procurement and production, is less widespread and has potential. The strategy of automating logistical processes, which can essentially be divided into five stages, thus plays a key role with regard to the profitability of a company. The aim of the article is to explain the five levels of automation in more detail and to classify them in the context of artificial intelligence. In this way, potentials are identified and applications of artificial intelligence are shown at the same time. A definition of the term automation serves a better structural orientation and gives the topic a theoretical framework. Furthermore, in order to make the topic easier to understand, it makes sense to classify artificial intelligence structurally and to take a closer look at its sub-areas. It is important to identify the resources required for the use of AI, but also to take a critical look at the functioning of algorithms in general.

2 THE TERM OF AUTOMATION

Since the concept of automation is used in many ways synonymous, it becomes clear only in the context whether it describes the name a work process (which means automating) or a work result or the work object processed by a task carrier (e.g. a machine or a computer) will. Furthermore, entire economic and technological development phases are characterized by the term, such as the age of automation, which gave their face to industrial revolutions. In the narrower sense, automation describes the inherent assessment of systems, acting by self-employed (autonomous) to achieve goals (Weller, 2008). Thus, in the first industrial revolution steam locomotive horse-drawn carriages, in the second industrial revolution, the assembly line production was normal. The use and discovery of new energy sources brought important inventions, such as the electric light or the automobile. Only in the third industrial revolution, the previously analogue automation by the invention of the integrated circuit, the microchip, continued that, for the first time digitally controlled industrial robots were used, the skilled workers supported in their activity and later replaced. The integrated circuits are considered a technological requirement for digitization and thus as the triggers of the digital revolution at the beginning of the 1970s entered the history. Robert Noyce announced in July 1959 the first "monolithic", thus formed from or in a single crystalline substrate, integrated circuit for patent. The main goal was: "[The] provision of improved equipment and line structures for the production of electrical [R] connections [...]" (Noyce, 1961). This technological progress was the birth of the digital technology known today and intelligent communication technology (ITK). Through the further development and the application of intelligent information technologies, by artificial intelligence (AI) or the Internet of Things (IoT), the fourth industrial revolution is shaped. The procurement department, entire production facilities and production lines as well as sales, therefore all procurement, production and sales logistics, are extended by network connections, provided that they have the necessary computer technology. From this time they generate a digital "footprint" on the Internet and are thus able to communicate with other systems.

3 THE DIGITAL TRANSFORMATION

The digital footprint of such a system leaves gigantic amounts of data (Big Data) and thus information from itself. The digital transformation can thus be understood as the first block, consisting of integrated circuits, for all the following digital evolutionary steps. If the analogue world translates into the digital world, it can now be formed from the binary codes consisting of zeros and ones, algorithms. This creates a repeating scheme, which should solve a particular problem as a unique action rule (Cormen et al., 2013). This scheme is able to automate processes and activities on a digital level. For example, monotonous devices whose sequence is constantly repeated by implementing an algorithm into a computer program, digital-automated. The computer program serves as a control e.g. for an industrial robot, which concretely translates and executes this action regulation in mechanical work.

Thus, algorithmic systems contribute significantly to the fact that numerous activities previously carried out by humans can now be automated. In this context, the definition of automation must be extended to be able to describe the operating process of a device or a machine so that it can be done in whole or in part without the participation of people activities can thus be worked. The merger of digitization and automation thus leads to IT-based atomization, or automation, which can be mapped in five stages. The following figure summarizes these stages in accordance with the CGI management consultancy. (Becker & Augsten, 2019)

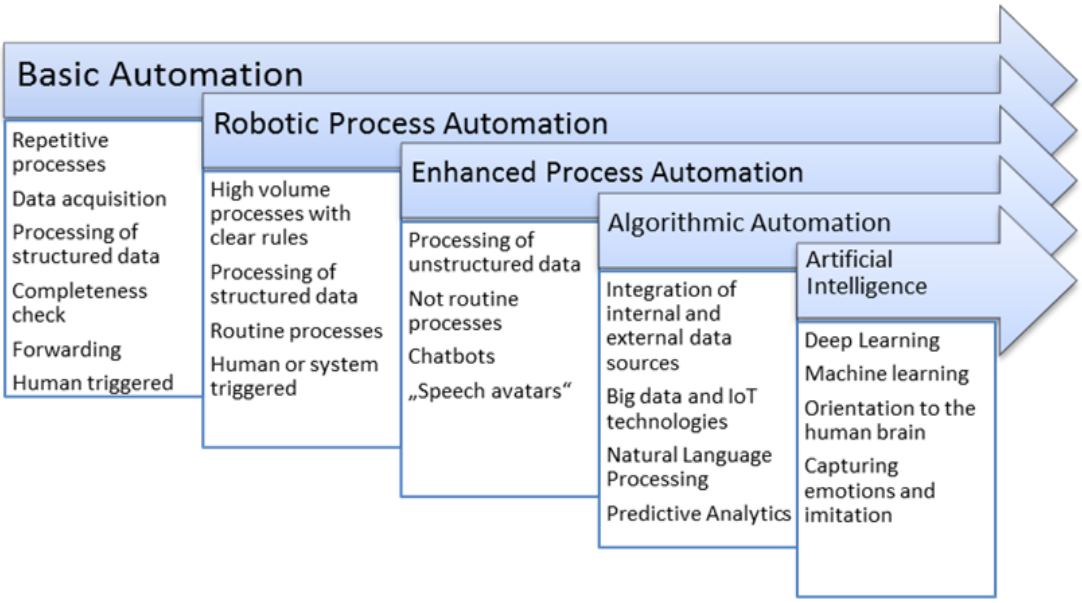

Fig. 1 – IT-based automation in business processes. Source: Becker & Augsten (2019)

The stages of IT-based automation developed according to CDI relate primarily to business processes outside production. They include a wide range of technologies that are used for the time being in sectors with administrative character (e.g., for banks and insurance companies), but increasingly adapted by procurement and production processes. While the basic form of IT-based automation is already established in the different degree in the companies, artificial intelligence is still in the infancy of research.

4 THE STAGES OF AUTOMATION

4.1 Basic Automation and Robotic Process Automation (RAP)

The first stage of "digital" automation finds its use predominantly with repeatable processes. They can be automated without greater effort, such as capturing standardized data, their review of completeness and forwarding.

Banks and insurance companies have already successfully expanded this first level and use the so-called Robotic Process Automation (RAP) - the second stage in this enumeration. Here, processes with high volume, large amounts of data but a clear structure and clear rules are automated. This enables a significantly faster processing of business processes and is therefore more efficient and cost-effective. The cost savings potential lies according to CDI in the low double-digit percentage range (CGI, 2021). A software accesses existing applications and automatically performs processes such as creating reports or processing invoices. In the second stage, the authorization by humans can already be transferred from the technical point of view. Whether this accompanying loss of control on this still quite low cognitive level is ethical, should be decided individually from case to case. Standing care and regular updates are nevertheless basically needed, as small changes in the applications can lead to a complete process failure. In the first two steps, initially routine operations are automatically automated.

4.2 Enhanced Process Automation

The third stage, Enhanced Process Automation, differs to the first two stages in that processes are automated with no routine processes and unstructured data. An example of this is the intelligent document processing, which must be adapted to the personal preferences of the

customers. Another application example can be found with the so-called chatbots, a technical dialog system that can be communicated via text input or voice input. Such systems are able to automatically process and reflect entries of customers or employees within the framework of internal corporate communications. Among others, manufacturers such as Microsoft or Amazon offer such "speech avatars" that are already in a position to perform simple bank transactions like a transfer. The cost savings potential is 20% to 50% in this area. (Becker & Augsten, 2019)

4.3 Algorithmic Automation

The fourth level, algorithmic automation, requires the integration of internal and external data sources. At this point in the digital evolution, technologies based on big data come into play. Large amounts of data are, so to speak, the food for algorithm-based analyses, which in turn enable or produce parallel technologies such as the Internet of Things or Natural Language Processing (NLP), i.e. the machine processing of natural language. Automated algorithmic systems that used to be human decision-making processes will in future also be subject to this transformation - or it is already being used by large information companies such as YouTube, Google and Facebook. In typical areas such as marketing, specifically in product placement, predictive analytics is finding its way or has already found its way. It describes a process that uses historical data to predict future events. A mathematical model is created from the historical data, which records important trends. This model, with the ability to predict impending events, is now applied to the current data in order to suggest actions that lead to the achievement of an optimal result (Siepermann, 2018). In insurance companies, such a method is used, for example, to predict the risk of accidents for different classes of policy holders.

4.4 Artificial intelligence as automation

In the last stage, the artificial intelligence (AI) are increasingly recorded technological advances. This is due, among other things, the steadily growing cloud capacity. The relevant energy for these data centres, which make it possible to store and process these data floods, the responsible persons from an ecological point of view against major challenges. In the fifth level, neuronal networks are used for the first time. More and more often the concept of deep learning is established, a multi-layered, deep learning, which reflect on numerous intermediate layers (hidden layers) a comprehensive internal structure of a neural network. Complex tasks, which fails a conventional, weak AI, should be to be overcome with it. Application areas could be in the classification of objects as well as in the image or face detection. Like Deep Learning, machine learning will attract the attention of research groups at the universities and colleges. The potential for efficiency enhancements and the associated reduction of scarce resources is great. When using artificial intelligence in technology areas for the purpose of automating tasks, efficiency increases of up to 65% result. In the field of process improvement, 60% are identified, regardless of the company size (Leichsenring, 2020). Thus, efficiency enhancements and process improvements are the largest drivers in the implementation of AI. This shows a study of corporate consulting Leichsenring, which includes the results from the surveys of 300 companies to this important technology trend. The figure below shows the most important drivers for the implementation of AI.

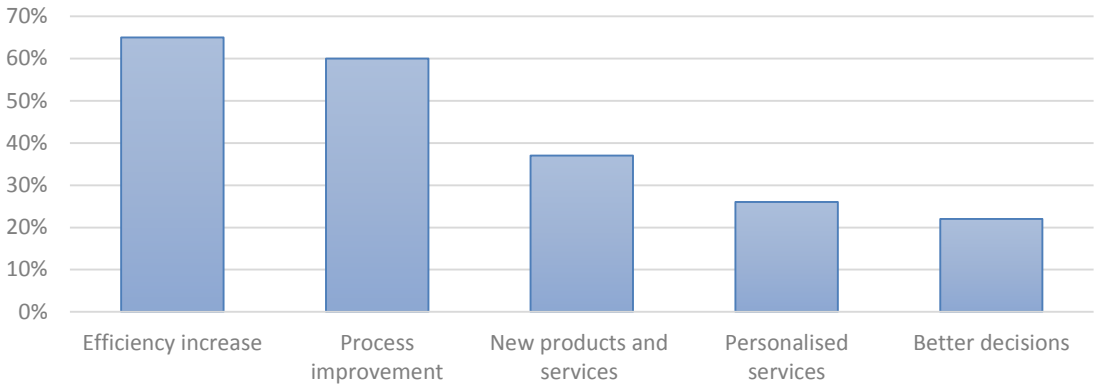

Fig. 2 – Motivators for the use of AI. Source: Leichsenring (2020)

The statements of the surveyed companies are congruent on the currently prevailing trend research regarding the use of artificial intelligence in the companies.

5 AUTOMATION INTELLIGENT BEHAVIOR

5.1 Classification of artificial intelligence

The concept of artificial intelligence (AI) is used as such in research and development, although there is a clear definition. This is mainly due to the fact that intelligence is used as a collective term for cognitive performance and is not exactly defined. Intelligence derives from the Latin "integer", which both recognizes, see, understand or in the literal sense means "choosing between". Intelligence could therefore be understood as a capability to solve a logical, mathematical, meaning-oriented or linguistically oriented problem. This context is decision structures of human commerce. The attempt to replicate exactly these decision structures is referred to in the general dialectic of science as artificial intelligence.

Today, AI is the focus of the already second wave of the digital transformation, whose beginning can be assigned to the year 2010 (Weißenberger, 2021). The first wave of digital transformation is equal to the digital revolution at the beginning of the 1970s. Artificial intelligence itself has already been discovered in the 1950s as a research area, explicit as a partial area of computer science. However, the AI first helped the availability of large amounts of data (Big Data), the global networking of systems and the development of high-performance hardware and software for breakthrough. In addition, there are technologies such as Edge computing, in the data streams decentralized and thus partially in place, i.e. on the edge of a network (e.g. directly on the terminal in the company) are processed. An approach requiring the use of terminals such as smartphones or notebooks, but not permanently connected to a network. Also cloud computing, virtually the counter-design on the edge computing, participate in the research field AI. This IT infrastructure is usually available over the Internet. The generated computer cloud or data cloud contains storage space, computing power or application software in the form of a service. With cloud computing, IT infrastructures are provided with a merger of various technical, primarily independent electronic systems without any of these applications need to be installed on local devices. Also powerful deep-learning algorithms and a variety of open source programs are to be assigned to the area of the AI (Buxmann & Schmidt, 2019).

5.2 Sub-areas of artificial intelligence

The concept of AI is associated with a wide variety of information technologies in the relevant literature and therefore a fundamental relationship between the terminology varies. The following figure shows the basic structure with the respective beginning of the establishment of the AI subareas:

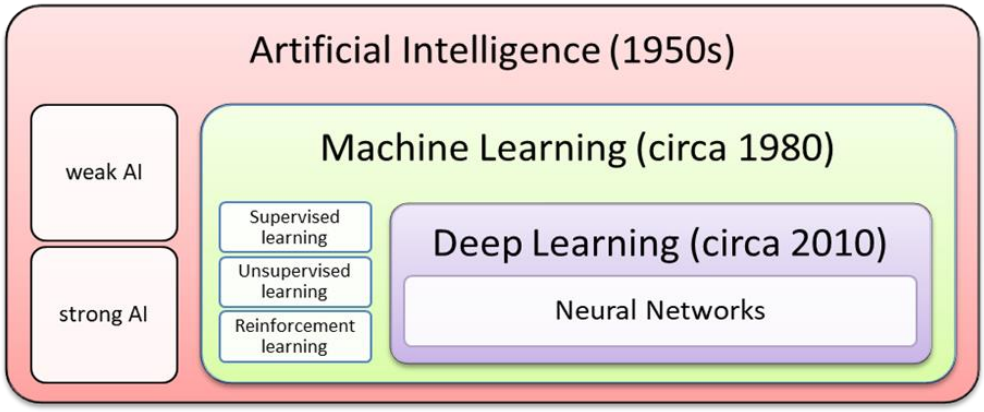

Fig. 3 – Sub-areas of Artificial Intelligence - basic structure. Source: own research

Basically, in the context of AI is always spoken of a weak and a strong artificial intelligence. The latter is still in their infancy in the face of their exploration. The dialectic of a strong artificial intelligence implies almost possible acting and working by people and machine at eye level. In contrast, weak artificial intelligence is only able to solve concrete application systems with a clearly defined target system. For example, the Russian Chess World Master Garri Kasparov was beaten in 1997 from the chess computer Deep Blue developed by IBM in six games under tournament conditions. In the sixth and last game against Deep Blue Kasparow had to accept one of the shortest defeats of his career (IBM, n.d.). Despite the impressive performance of Deep Blue, the skills of the chess computer are limited to playing the chess, which - consists of sober - consists of it, trains (ways to place game figures on the field), with moves to reciprocate and thus a permanently defined goal (the To hit opponent king) under certain conditions. Thus, Deep Blue followed an algorithm whose goal is to win a chess piece. In addition, the analysis of all public chess games included in the programming, which causes the chess computers to have a complete history of possible strategic game variants. Thus, although the calculator is "chess expert" but still unable to compete with human intelligence. Human intelligence would be able to abstract and adapt a concrete problem to other problems. Deep Blue, here representing weak artificial intelligence, cannot do so. For example, he is not able to solve a sudoku, the application to other problems remains forbidden to the computer. In fact, the computer has no knowledge of the meaningfulness of the chess game, neither the parameters "Why I play" as well as "what I play" are unknown to him. Thus, the "machine" is fundamentally different from the "man", which often looks for his drive and motivation in the "Why" and at best.

5.3 Machine learning

Machine learning is considered as a partial area of artificial intelligence. Simplified in the machine Learning is the gradual defined processes through artificial neuronal networks in different contexts. Step by step is taught a machine with the help of the methods and techniques summarized under the preamble machine Learning, like a human being "to think". This learning process will perform the development of a weak to a strong AI. If today is spoken of artificial intelligence, weak AI is usually meant. Basically, in principle, it is about identifying patterns of statistical relationships (correlations) within the present data. The amounts of data are very

large (Big Data) and corresponding IT infrastructure is assumed for this task of pattern recognition. Now there are several methods, as the learning process can be done in mechanical learning (see Figure 3).

Supervised learning: Monitored learning uses test data or training data for the learning process. These data not only contain input values (for example, object ratios) but also the desired result. In a face detection, for example, images of faces are used as an input variable, which are also charged as a face. The machine-learning algorithm now determines a function based on the existing and fed training data, with which the input data is suitably mapped to the result. The machine-learning algorithm continues to adjust this function independently and refines this as long until the desired success rate is reached. Thereafter, the learning process is verified with the aid of the training and test data. This technique is used, for example, in clustering methods, i.e. the discovery of similarity structures with mostly large databases, where the clusters are known in advance.

Unsupervised learning: In contrast to supervised learning, the unsupervised learning input data is used, where the result is not yet defined, e.g., pictures of faces without label. The algorithm should recognize patterns in the input data based on certain features. This technique can be used for clusters of data in which the patterns or the target values that arise from this are not known. For example, data records can be present about the size and weight of men and women, but still no gender-specific assignment of the data is possible for the time being. There is therefore still ignorance to whom this data is exactly allocated. Only when the machine detects a pattern with the aid of an algorithm, which is characterized by deviation from the structureless noise, an artificial neural network can orient itself to the similarity to the input values and there is an assignment (Ghahramani, 2004). As with sorting a fruit basket with different fruit varieties, fruits are summarized with the same or similar characteristics and thus incorporation of the features are green and round or yellow and oblong (see Figure 4). This cluster created from the segmentation can then be assigned to the fruit varieties.

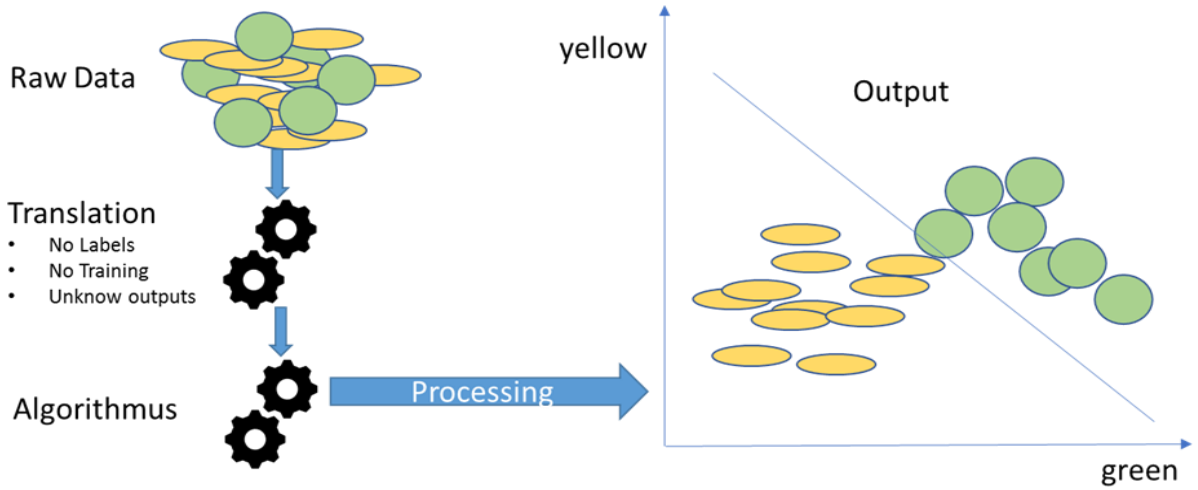

Fig. 4 – Unsupervised learning. Source: own research

The method generally described here, which is often used for surmounting, is often referred to as cluster analysis or agent analysis. It sees itself to discovering similarity structures within large amounts of data and often finds application in market research. These clusters found so can be divided into different methods. In principle, they are distinguished after a graph-theoretical, optimizing, partitioning or hierarchical method. The two latter methods are often used in combination. The partitioning cluster analysis goes off from a given classification of the elements and try to improve them by regrouping while hierarchical cluster analysis on the

basis of selected characteristics tries to identify homogeneous groups. These methods are used, for example, in the media world to identify market segments and thus to send target group-oriented advertising at the optimal time.

Reinforcement Learning: The concept of reinforced learning is borrowed to psychology and has already been used in the beginnings of cybernetics from the American scientist Marvin Lee Minsky in his dissertation in 1954 in 1954. In the 1980s, the term was revived and finally used in 1996 by Bertskas and Tsitsiklis to capture the idea of the field as a combination of neuronal networks and dynamic programming (Sutton, 2004). Reinforcement Learning can be understood as a number of methods of machine learning, in which the computer program (software agent), which is capable of certain autonomous behaviour, has learned independently a strategy. In contrast to supervised and unsuited learning, the agent is not presented, which action is the best in terms of a situation, but the software receives a kind of reward at certain times, on the basis of which the agent is a benefit function, which describes the preferences of economic eggs mathematically. This function then describes what value has a certain state or action.

6 POTENTIALS AND APPLICATIONS OF ARTIFICIAL INTELLIGENCE

In a study of McKinsey & Company's corporate and strategy consulting, eight different areas have been identified in which artificial intelligence show particularly high development potential. These ranges from autonomous driving over automated support processes, automated quality inspection, automated quality optimization, supply chain management, predictive maintenance (a pro-active machine maintenance), human machine and machine interaction up to research and development (Bauer et al., 2017). The possibilities of use depend essentially whether these potentials can be identified in the individual disciplines, such as controlling or logistics at all, in other words: Is there any problem to be solved or the integration of AI in the companies becomes End of yourself?

In order to use the potential of AI, provided they are identified and defined exactly related objectives in the company, different resources are necessary for the applications of artificial intelligence. These range from appropriate hardware, qualified employees to pure availability of large, structured data. A frequently occurring problem arises by which criteria should be recognized patterns from which statistical procedures (correlations) can provide information about certain issues. Artificial neural networks are usually to be understood as a "blackbox" and the traceability of the criteria where patterns are recognized is difficult or even not comprehensible from the programming of these algorithms. Thus, new patterns are formed from created patterns, which leads to the fact that the actually underlying cause of the decision is no longer identifiable - a "why" of the decision remains unanswered and guilty leads to ethical questions. As a result, a further research requirement can be derived with regard to the so-called algorithm ethics and can be explained using the example which is present outside the logistics and understood as a prediction in the logistics context.

The Start-up "Credit Pitch", which operates in the financial services area and thus decisions about credit charges, uses, for example, up to 20000 data points per lending decision (Yogeshwar, 2018). This data is also generated for social networks such as Facebook, Twitter or Instagram and determine the credit risk of a customer within a minute - an expertise that would have taken for days or even weeks under traditional valuation methods. Although the precision to determine creditworthiness is very high, it cannot determine the reason in the event of rejection of the loan. The reason for this is due to the fact that the functioning of algorithms is always a statistical conclusion. Accordingly, misinterpretations are not excluded, with

failures, which is discussed under the term "algorithmethy" (Zweig, 2018). This type of decision-making with the absence of reasons requires critical assessment. In an enlightened society, the knowledge of the cause following an effect is an elementary design tool for future actions.

7 POTENTIAL OF ARTIFICIAL INTELLIGENCE IN LOGISTICS

Logistics has advanced to the secret supreme discipline of business administration in recent years. Excellent strategic management is just as important a prerequisite for the success of a company as a solid financing model, but there is hardly any other area that has come into the priority focus of customers as much as logistics. If, for example, supply chains are not adhered to, the entire value chain is frozen, which in the worst case means the company becomes insolvent. Large companies, especially in industry, also see potential savings of up to 20%. However, a survey of 100 logistics decision-makers from large industrial companies revealed that, despite increasing digitalization, 75% of companies do not have an overview of their cost structure, and as many as 80% stated that the processes related to the supply chain are not yet sufficiently automated. (Jüngst, 2019)

One of the promising potentials that artificial intelligence seems to promise in connection with big data is the determination of needs, which in the "old world of logistics" was understood more as art than science. State-of-the-art computing technology and analytics paired with machine learning and artificial intelligence help companies that use these methods to achieve great competitive advantages. However, leading companies here come more from the consumer goods sector or from the high-tech sector.

Another potential arises from the possibilities of networking. These possibilities are currently largely unused due to non-standardized data interfaces and non-integrated planning. This applies both to the internal view of the company's own supply chain, as well as to the external view when it comes to the integration and networking of business partners.

Decision management can also be expanded. Decision-oriented management is essentially based on the intention to gain descriptive or prescriptive statements. It is precisely this normative decision theory that does not want to describe decision-making processes as such, but rather to give advice on how to solve decision-making problems (Laux et al., 2018). Companies that do not want to be left behind in this area should - or have to - invest in business intelligence or AI. The focus here is not only on improving performance, but also on the speed at which certain information is received in order to gain knowledge from it. Gartner expert Tine Dalby Joergensen assumes that many AI projects will be launched in 2020/2021 or implemented in the digital plans of the supply chain department (Semmann, 2020).

8 ROBOTITIC PROCESS AUTOMATION AS COST-EFFECTIVE APPLICATIONS IN LOGISTICS

A comparatively inexpensive alternative to the very expensive implementation of artificial intelligence is Robotic Process Automation (RPA), which is sometimes also referred to as a software robot or bot (Safar, 2021). It represents a comparatively simple way of automating processes and thereby reducing operational costs and significantly increasing the efficiency of the processes. RPA describes the second level of IT-based automation and can therefore be expanded with regard to further automation steps. Nevertheless, the automated sequence of processes with the help of software that is able to emulate the behaviour of human interaction is achieved through a kind of synchronization of the human-machine interface. RPA robots can thus communicate with various systems and enter, retrieve and interpret data. For a continuous

process flow, a data exchange free of media breaks is necessary. Employees should therefore use the same interface as the people who would normally enter these tasks manually into a data processing system. This means that the transition point for data exchange from a non-technical system (human) to a technical system is identical and enables smooth data exchange and efficient data processing. There is no need for time-consuming programming of an application interface by imitating user input. For this process, the software robot logs into various applications and carries out the tasks previously carried out by employees. Robots can thus pass on the human-simulated behaviour to other devices and work collaboratively. They are therefore ideal for automatically performing repetitive tasks that follow clear rules. Software robots usually act just like their human users. This makes expensive new IT systems and their maintenance obsolete, and with them the time-consuming, legally prescribed system tests. Companies can therefore gain decisive competitive advantages in the market with well thought-out and well-designed RPA consulting. However, such companies should rethink their strategy to externalize this topic or to fall back on crowd solutions or collaborative solutions due to the often found industry-remote nature of such an IT concept outside of their core competencies. Well thought-out RPA consulting by an external service provider can therefore lead to great time and cost savings with little effort.

Robotic Process Automation is particularly suitable for all processes that can be mapped well using an algorithm and therefore follow clear instructions. In principle, the software technology has been designed for the automation of the front and back office processes. Especially in the context of the front office area, i.e. the infrastructure of a company that interacts with the customer, new standards and thus new tasks in value chain management are defined. The possible uses of smart process automation through RPA are diverse. The following examples give an impression of the wide range of possible applications.

Automated scheduling of shipments: RPA bots can already do the automatic input and the automated planning of shipments. For example, the software can read shipping information from emails or other text-based electronic mail, enter customer or supplier data into a system and consequently create a corresponding shipment. As the process continues, the bot informs the back office, which activates internal processes in a timely manner (e.g. in accounting) based on the new status. Furthermore, if so desired, external logistics partners or customers are automatically informed of the status of the created shipment.

Automatic email communication: E-mail is the most important operational means of communication across all industries. According to Carius and Scheufele (2018) from Bitkom, an average of 21 e-mails per day reached the business mailboxes in 2018. Decision-makers and employees with an administrative field of activity communicate more often via email than employees with a more practical profile. Even in times of alternative communication media beyond electronic mail, managers have to sort, evaluate and, if necessary, answer the high number of e-mails. With a weekly working time of 40 hours, around eight hours per week are used for this (Töpper, 2014). The number of people who use e-mail as a means of communication continues to rise, and with it the number of e-mails sent. The following figure shows the percentage of the German population who used the Internet to send and receive emails. Germany was thus above the average data traffic in the European Union, which was 74% in 2020 (Eurostat, 2021).

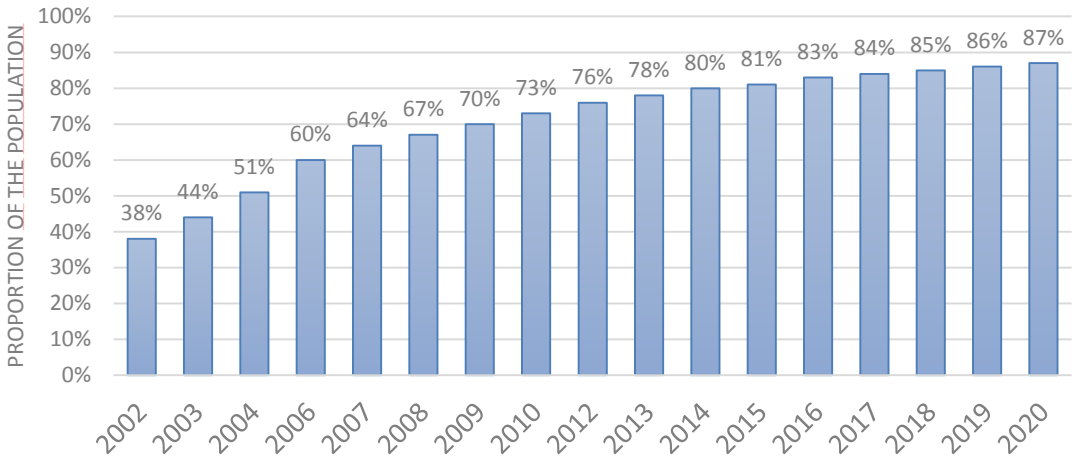

Fig. 5 – Share of e-mail users in the population in Germany until 2020. Source: Eurostat (2021)

It can therefore be assumed that this trend is not only valid in the private sector and will continue to grow, but also tends to increase in the business and entrepreneurial environment. Correspondence via e-mail in the B2B and B2C area is due to increasing networking on the one hand and increasing security thinking in the legal sense on the other. The burden of proof of an email, which is available or reconstructable at any time, is considered in the legal sense (under certain conditions and framework conditions) as an offer and / or acceptance of the offer and can also be used in court in the event of a legal dispute. In order to cope with this flood of information, efficient process management of this kind will in future be necessary to optimize communication by e-mail, reduce error rates and ensure legal security.

RPA bots are able to automate all email communication and increase response speeds. Communication between the customer and the company is thus significantly accelerated and qualitatively improved. For example, as soon as the shipment status has changed in the system, the RPA bot automatically forwards this information by email to the customer, who is always as well informed as possible about the delivery status of his shipment. Companies like Amazon have been using these possibilities for years, in smaller companies the feasibility of such technological possibilities mainly depends on the degree of digitization.

Transfer of packages in customer service through chatbot in combination with RPA: The possible uses of RPA can be expanded in combination with other digitization technologies to the extent that the customer's delivery address or the delivery date of a shipment deviates from the customer's original order and must be changed. Logistics companies can completely automate this process with the combined use of a chatbot in combination with RPA. The change request from the customer or the supplier is recorded by the chatbot, the necessary data, such as the shipment number or the new recipient address, are recorded and forwarded to an RPA bot. Here, the changed information is compared with a logistics system (e.g. an enterprise resource planning system), updated and the completion of the process is confirmed by passing this data on to the chatbot, which sends the information to the customer or supplier in the form of a confirmation email sent.

9 CONCLUSION AND RECOMMENDATIONS FOR ACTION

Digitization and all the associated dialectics offer great economic opportunities, especially for the logistics industry. The possibilities that arise from big data, such as the digital networking of all processes within a supply chain, lead to a significant reduction in the workload of

employees and can reduce the efficiency of each Significantly improve the company. The following recommendations for action for companies are thus postulated:

1. For the optimal use of the possibilities offered by digitization, AI and big data, there is a need to evaluate both the core and support processes for possible uses for RPA or even AI. This is the prerequisite for increasing efficiency and saving time for value-adding activities.

2. It is advisable to carefully examine the type of AI technology with regard to process automation for each company. Not every technology can be used meaningfully for the specific problems of the company.

3. Furthermore, before implementing RPA or AI, data availability and data quality must be checked. Due to infrastructure, political or geographical factors, data availability can be a major hurdle.

4. Companies should use the existing resources and infrastructures from already past pilot projects with implementation character. In the case of an initial implementation, it is advisable to use the experience of experts and IT specialists. A written agreement is urgently recommended, especially with regard to guarantees regarding data availability or data loss.

5. Finally, the creation of a concept for an implementation of the systems and technologies is advisable, which also does justice to a comprehensive approach and can be flexibly adapted to changes. Processes can change organizationally as well as technically within the company. This need for change should be taken into account.

The recommendations for action are heavily dependent on the degree of maturity of digitization, i.e. on the company's already collected experience with regard to AI and RPA. If there have hardly been any points of contact with the technologies in the past, it is advisable to first examine AI by identifying suitable potential. These should then be discussed and logged at management level in order to serve as a concept template if necessary.

If there is already advanced use of AI and digitization, knowledge about the topic should be continuously built up. A possible development of an AI team is advisable from a company size of 30 employees and more, taking profitability indicators into account. Training on the topic promotes understanding and helps to create a concept for the use of AI. The usage case should have scalable parameters in order to specifically evaluate the later results.

If a company has already gained experience with RPA and AI, a strategy-compliant use of a structured process model with a focus on an end-to-end view of business processes is recommended. A number of questions should be discussed and assessed critically on an equal footing with economic aspects. The targeted development of AI talents and collaboration with start-ups makes economic, social and ecological sense. In this way, jobs can be created that focus on conserving resources with the help of digital technologies as the primary objective and are therefore economical and sustainable at the same time.

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UV ACTIVATED PERSULFATE FOR DECOLORIZATION OF CONGO RED

Juraj Michálek, Lenka Blinová

Abstract

Dye-contaminated wastewater is one of the biggest environmental problems in the world. With the constant growth of the industry, more and more dyes from production are entering water bodies. This study focuses on the removal of one of the proven toxic dyes. The decolorization of congo red (CR) by using UV activated persulfate (PS) was investigated. For PS activation, 125 W medium-pressure mercury UV lamp was used. The efficiency of decolorization was measured by UV/Vis spectroscopy and the results are shown as a ratio (A/A_0) versus time graphs. For comparison, the degradation of CR by UV alone and UV/H_2O_2 was also performed. These different processes caused the initial pH of the decolonization process to be different and pH after treatment also changed slightly. Different concentrations of PS were used to find the highest efficiency of CR decolorization. The highest decolorization of 25 mg L^{-1} CR solution was 100% after 20 minutes with 10 mM of PS concentration. The results of experiments showed that the degradation of CR by UV/PS process can be described with a pseudo-first order kinetic model. Based on these results, it can be concluded that the UV/PS process is one of the options for efficient removal of congo red.

Keywords: *congo red, decolorization, dye, UV, persulfate*

1 INTRODUCTION

The current increasing pollution of water bodies is the result of increasing urbanization and industrial growth. The major harmful industrial effluents come from dyeing of plastic, paint, food and leather (Luo et al., 2020; Singh et al., 2015). It is estimated that 7×10^5 tons of various colouring from about 10^5 commercially dyes are manufactured each year and 2.8×10^5 tons of textile dyes are discharged in textile effluent each year worldwide (Katheresan et al., 2018; Singh et al., 2015). Dye wastewater may seriously harm the freshwater resources due to absorption of the sunlight which disrupts natural photosynthesis of water plants and it leads to much lower concentration of dissolved oxygen and lower self-cleaning capacity. Textile dyes are often derivates of aromatic compounds, which has strong biotoxicity and certain carcinogenic, teratogenic and mutagenic effects to humans and animals (Abe et al., 2018; Luo et al., 2020).

2 THEORETICAL BACKGROUND

Congo red (CR) is one of the most commonly used azo dyes which is reported to be non-degradable. The presence of this dye in water causes several environmental and health related problems (Shah et al., 2020).

Physical, biological and chemical methods can be used for the removal of dyed wastewater. Various technologies including adsorption, coagulation, flocculation and reverse osmosis has been tested. Some of these methods resulted to significant removal of dye, but the cost and production of a secondary waste products are limiting factors (Elahmadi et al., 2009). Advanced oxidation processes (AOPs) gained a lot of attention for dye wastewater treatment because of high treatment efficiency and wide range of applications. The processes are based on production

of high reactive hydroxyl (•OH) radicals with redox potential E_0=1.9-2.7 V (Elahmadi et al., 2009; Oh et al., 2016). In the recent years, there is a lot of studies based on persulfate (PS) AOPs in water treatment. Due to high redox potential of sulfate radical $SO_4^{-\bullet}$ (E_0 = 2.6-3.1 V) it has strong oxidization capacity which brings new prospects in wastewater treatment. Sulfate radical has comparing to hydroxyl radical a longer lifetime ($t_{1/2}$ = 30-40 μs and $t_{1/2}$ = < 1 μs, respectively) and it allows excellent mass transfer and contact between $SO_4^{-\bullet}$ and pollutant (Oh et al., 2016). Catalytic activation of sulfate radicals can be achieved with heat, UV radiation (Eq. 1), transmission metals, electrolysis, radiolysis, ultrasound, ozone, etc. (Krawczyk et al, 2020; Qiao et al., 2019; Ushani et al., 2020).

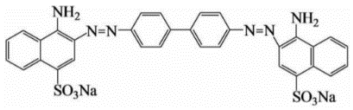
$$S_2O_8^{2-} \xrightarrow{\Delta/UV} 2SO_4^{\bullet -} \quad (1)$$

3 MATERIALS AND METHODS

3.1 Chemicals

CR and potassium persulfate were obtained from LACHEMA (Czech Republic). Hydrogen peroxide (30% w/v) was obtained from MIKROCHEM (Slovakia). Distilled water was used in all of the experiments. The basic properties and structure of CR are shown in Tab. 1.

Tab. 1 – Congo red properties and structure. Source: Raharinirina et al. (2009)

Chemical formula	$C_{32}H_{22}N_6Na_2O_6S_2$
Name	sodium salt of benzidinediazo-bis-1-naphtylamine-4-sulfonic acid
Molecular weight	696.68 g mol^{-1}
Absorption maxima (λ_{max})	497 nm
Molecular structure	

3.2 Analytical

A pH meter Multi 340i from WTW equipped with SenTix electrode was used to measure acidity before and after treatment. Decolorization of CR solutions was determined by UV/VIS spectrophotometer GENESYS 8 using 1 mm thick quartz cuvette. The maximum absorbance for CR is at 497 nm. Due to change of CR solution pH after adding PS from 6.6 to 2.9 – 3.3 (depends on PS concentration) the colour of dye was changed from red to blue-violet and the maximum absorbance shifted from 497 to 570 nm. The efficiency of decolorization was calculated using following formula:

$$\eta = \frac{A_0 - A}{A} \times 100 \quad (2)$$

where A_0 is the initial absorbance of the CR solution and A the absorbance at time of the degradation.

3.3 Experimental procedure

Firstly, a 50 mL of CR solution (25 mg L^{-1}) and PS (1 mM, 5 mM and 10 mM) or H_2O_2 (100 mM) were prepared in 100 mL beaker and then the solution was put in the UV reactor. All the experiments were performed at natural pH. For the UV alone the natural pH of CR solution was 6.6, natural pH of CR/H_2O_2 was 5.5 and natural pH of CR/PS was 3.3, 3.1, 2.9 for 1 mM, 5 mM and 10 mM PS concentration respectively. The UV source was provided by medium-pressure mercury UV lamp (125 W), which tap water cooled and placed in quartz jacketed

vessel. The outside of the reactor was covered with an aluminium foil. The scheme of UV reactor is shown in Fig. 1. The mixtures were analysed after different contact times (5, 10, 20 and 30 minutes). All the experiments were performed in triplicates.

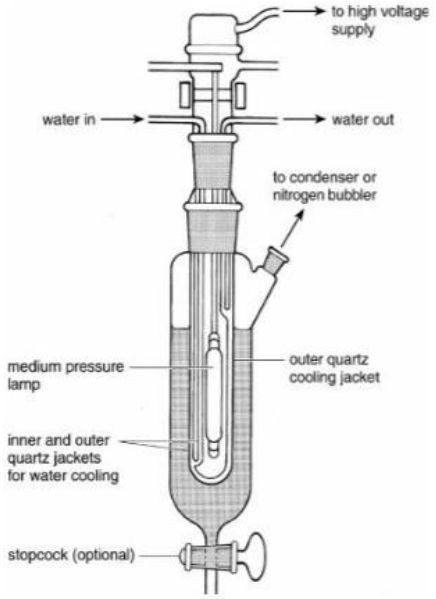


Fig. 1 – The title of the figure. Source: own research

3.4 Kinetic study

For the decolorization of CR by sulfate radicals was used a pseudo-first order kinetic model, which can be described by Eq. 3 (Krawczyk et al., 2020):

$$\ln\left(\frac{C_0}{C_t}\right) = \ln\left(\frac{A_0}{A_t}\right) = k_{app}t \tag{3}$$

where C_0 and C_t are the initial and time-depended concentrations, which are proportional to the measured absorbance A, and k_{app} is an apparent rate constant.

4 RESULTS AND DISCUSSION

4.1 Comparison of UV alone, UV/H_2O_2 and UV/PS process

As shown in Fig. 2, the decolorization of CR was performed with different processes for comparison of efficiency - UV alone, UV with H_2O_2 (source of $HO^{\bullet}$), UV with PS (source of $SO_4^{-\bullet}$). We can observe that the initial ability of UV/H_2O_2 remove CR is faster compared to UV alone, the resulting removal after 30 minutes is almost the same (89% for UV alone and 92% for UV/H_2O_2). The best efficiency of decolorization was reached using UV/PS (PS concentration: 10mM), where 100% of CR was removed after 20 minutes.

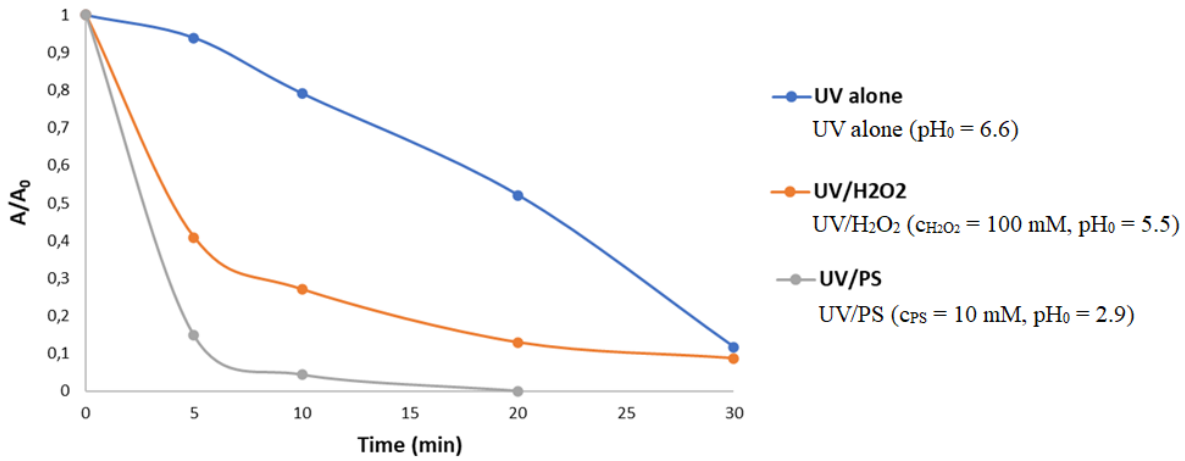


Fig. 2 – Comparison of CR decolorization with different processes. Source: own research

While the concentration of H_2O_2 is ten times higher than in the case of PS, the generated hydroxyl radicals did not react with CR as effectively as sulfate radicals. This difference may be due to different reaction mechanisms. Sulfate radicals works more by electron abstraction and hydroxyl radicals more by hydrogen abstraction or addition. This makes sulfate radicals are more selective and highly reactive towards organic contaminants containing non-bonding electron pairs of atoms such as O, N and S (Krawczyk et al., 2020).

The pH after treatment slightly changed from the natural one. The values are given in Tab. 2.

Tab. 2 – Change of the pH. Source: own research

Process	pH before treatment	pH after treatment
UV alone	6.6	5.5
UV/H_2O_2	5.7	4.6
UV/PS	2.9	2.2

4.2 Effect of PS concentration

As mentioned above, the colour of CR changed significantly after the addition of PS (there was change in pH). Fig. 3 shows CR solution before and after the addition of 10 mM PS and after 20 minutes of treatment with UV/PS process.

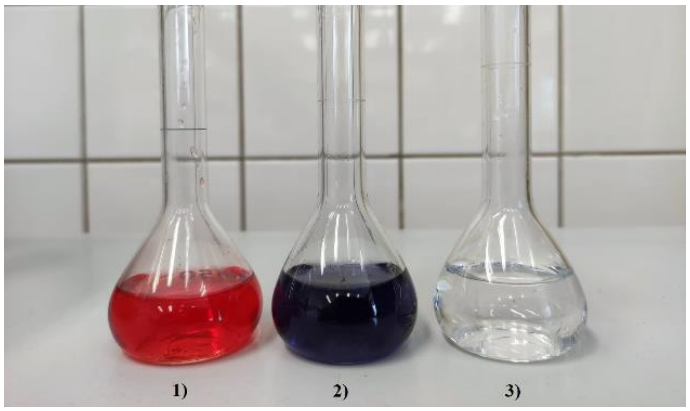


Fig. 3 – The change of CR colour (before – 1), after – 2) PS addition and after treatment – 3)). Source: own research

Different concentrations of PS (1 mM, 5 mM and 10 mM) were used to determine the optimal conditions of decolorization. Fig. 4 shows the decolorization kinetics of CR.

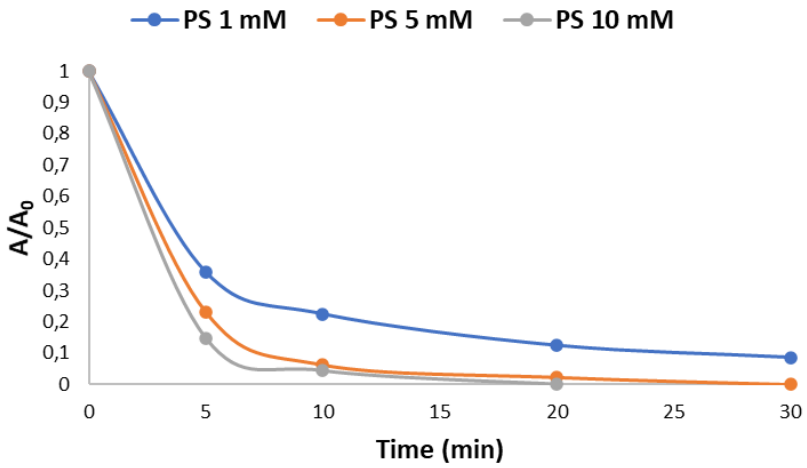


Fig. 4 – Effect of PS concentration on decolorization of CR. Source: own research

PS with the concentration 1 mM reached 84% decolorization of CR. This may be cause of the low concentrations of PS did not produce enough sulfate radicals. The degradations of CR with 5 and 10 mM of PS were very similar. The degradation efficiency was 96% for 5 mM and 100% for 10 mM after 20 minutes of treatment.

In Tab. 3 are shown kinetic constants (apparent rate constants k_{app} and correlation coefficients R^2) for the pseudo-first order kinetic model for the different concentrations of PS.

Tab. 3 – Pseudo-first order kinetic constants of UV/PS degradation. Source: own research

PS concentration	k_{app} (min^{-1})	R^2
1mM	0.07	0.99
5 mM	0.17	0.98
10 mM	0.24	1

The apparent rate constant increases with increasing PS concentration and the correlation coefficients are almost equal to 1 which suggests that this process can be described by a pseudo-fist order kinetic model.

5 CONCLUSION

UV/PS process is a very effective method for the degradation of industrial or textile dyes. In this study, CR was used as a wastewater contaminant. The decolorization of this toxic dye was performed by activation of potassium persulfate by medium-pressure mercury 125 W UV lamp. The results showed that adding 10 mM of PS removed 100% of CR solution after 20 minutes. In another study, it will be appropriate to monitor the effect of pH, the formation of intermediates, total organic carbon removal and the resulting toxicity after treatment.

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FAMILY EMBEDDEDNESS AND INVOLVEMENT IN INTERNAL MIGRANT'S TOURISM ENTREPRENEURSHIP INTENTION: A CONCEPTUAL STUDY

Thi Tuong Vy Nguyen, Kumar Sandeep Dey, Duc Sinh Hoang

Abstract

The wave of migration is remarkably growing, and the entrepreneurial migrants is increasingly showing their importance role and contribution in socio-economic development. However, existing literature on migrant entrepreneurship raises much more attention on global or trans-national migrants, while under researching internal migrant's entrepreneurship. Anchoring on Embeddedness theory with focus on family embeddedness perspective in the context of tourism, this conceptual study aims to analyse internal migrant's intention toward entrepreneurial tourism business the role of the family involvement. The study will employ a mixed research approach of both qualitative and quantitative methods including in-depth interviews with managers and experts together with questionnaire survey alongside PLS-SEM for both local and internal migrant entrepreneurs in tourism. Our expectation is to explore the challenges confronting internal migrant's entrepreneurial intention in comparison with their native counterparts as well as the moderating role of the family involvement on their business intention.

Keywords: *entrepreneurship intention, family involvement, internal migrant, tourism*

1 INTRODUCTION

Migration and tourism have a complex interrelationship. In some case studies, they promote each other, while in others, the opposite practice arises. Research on employment and entrepreneurship issues in countries with rapid tourism economic growth has been extensive, but still has not kept up with the link between tourism and migration, especially internal migration as well as the factors affecting this relationship, such as family embeddedness. (Choe & Lugosi, 2022; Xiong et al., 2020; Bird & Wennberg, 2016).

Migrant entrepreneurship has been considered as a crucial socio-economic phenomenon and having been explored in different disciplines with emphasis on their important role and efficiency. However, migrant businesses attract much attention from researchers on the aspect global movement or immigrant, while there is still limited existing literature on internal or domestic migrant entrepreneurship. On the one hand, entrepreneurial migrants, due to the different living style and culture, could make more diverse and unique products and services, attracting users in host countries, thus, are likely to be more engaging in entrepreneurship than the natives (Guerrero et al., 2021; Liu et al., 2019; Saridakis et al., 2019). On the other hand, they may face many barriers, not only the ones that are similar to those faced by domestic firms, but also those that are typical of migrant businesses, including lack of local networks, unfamiliarity with the local business environment and language and cultural barriers. (McAuliffe & Khadria, 2020; Etemad, 2018).

Relating tourism, among different economic sectors, it is usually considered as having a high potential to create more jobs, generates remarkable revenue for destinations, and boost economic and social development (Huynh et al., 2021; Xiong et al., 2020). In more details, tourism can also motivate for internal migration from urban to rural destination, not only due to entrepreneurial potential but also to more enjoyable living environment in such destinations

(Varmazyari, et al. 2017). As universal mobility increases and the link between tourism and migration become deeper, further studies on their relationships, critical issues and future directions are essential (Choe & Lugosi, 2022; Adams, 2020; Bianchi et al., 2020).

However, as mentioned above, existing research on migration and tourism are still limited and mainly on the external immigrant entrepreneurship. The still-opened question is whether internal migrants face the same challenges or have the same opportunities as their external counterparts when their movement is out of the city/region they are living, but still in the same country instead of moving out of their home country. And does the family involvement, at different levels, have any impact on the internal migrant's association with entrepreneurial intention especially under some critical events such as the COVID-19 pandemic?

2 THEORETICAL BACKGROUND

2.1 Internal Migrant Tourism Entrepreneurship

Pursuing entrepreneurial business in overall is not an easy decision. First of all, there must be an attractive opportunity to form a business project that generates economic surplus in the short and long term. Next, these opportunities must be feasible for potential entrepreneurs. Because despite the existing opportunity, these businesses can be blocked by *"very high minimum effective scale requiring large amounts of capital investment"*, especially in cases where these the founders do not have sufficient own capital. The rules and regulations emanating from the government/agency of the destination are also significant barriers for the newcomers (Ismail et al., 2019; Kloosterman & Rath, 2001).

On another aspect, whether these individuals being local or migrant may be a factor affecting their entrepreneurial business intention, especially in the tourism sector. For migrant entrepreneurs in general and in the tourism sector particularly, there are many resource differences (human, financial, social and cultural capital) compared to their native counterparts. Specifically, many studies suggest that migrants often suffer from a lack of start-up capital and local market knowledge, which should result in a relatively high failure rate (Li & Johansen, 2021; Kloosterman & Rath, 2018). In term of tourism, over the past few years, the industry has become increasingly vulnerable to threats including financial and economic instability, political crises, rising oil prices, accelerating global environmental change, and more. demand (Ismail et al., 2019), and pandemics (Kaushal & Srivastava, 2021). These challenges can prevent individuals (migrants) from starting a tourism-related business.

However, among different types of migrant business on tourism, there are limited entrepreneurial studies concentrating on exploring the intention of internal migrant toward entrepreneurship in this sector. According to International Organization for Migration (2019), *"internal migration or domestic migration is human migration within a country. Internal migration tends to be travel for education and for economic improvement or because of a natural disaster or civil disturbance".* Although there has been an increasing trend of people moving domestically from one province to another to live and/or find works or opportunities to develop tourism businesses (Sun et al., 2020; Massidda & Piras, 2015; Deshingkar & Grimm, 2005), existing research on in-migrant's tourism business just focuses on labourers more than entrepreneurship. Typically, examining the internal integration to new destinations of migrants, both studies of Sun et al. (2020) and Dempster and Zimmer (2020) have just explored these migrants' aim to position of workers in tourism, not opportunity for entrepreneurial intention. Hence, it is necessary to further explore the aspect of arising entrepreneurial spirit among internal migrants in tourism sector as well as factors impacting their intention.

2.2 Family Involvement

While many tourism businesses are found by individual owners or couples as business partners, family-owned or family-involved business is also popular. Whether or not there is the involvement of family may be a factor affecting tourism entrepreneurial intention. Studies on the subject of family business and entrepreneurship have suggested that family involvement in business confers special resources, called 'familiness'. These resources may include financial support, long-term orientation and counselling, altruism, and high level of family trust (Li & Johansen, 2021). Else, the tie will be stronger within the family-owned business.

Family business dominates most economies worldwide (Kraus et al., 2018) and becomes a crucial entrepreneurial model for the tourism industry in both developed and developing countries (Peters & Kallmuenzer, 2018; Arcese et al., 2020). Opportunities for rather easy sector-entry appeal to family entrepreneurship. People interested in outdoor recreation can start tours or outfitting companies or provide facilities. Those with rural property can establish farm stays, campgrounds, and bed-and-breakfast houses (Getz & Carlsen, 2005). Besides, family enterprise development potentially makes trans-generationally entrepreneurial culture one of the main economic engines of the tourism sector (Peters & Kallmuenzer, 2018).

Focusing on migrant entrepreneurship, a few studies also find that the migrant can draw upon these unique, family-related resource endowments to overcome the difficulties associated with business start-up, contributing to business survival." However, limited studies have been interested in comparing the likelihood of receiving family support among local and migrant entrepreneurs in tourism, as well as whether this family involvement can make a difference in encouraging their entrepreneurial intention or maintain their business under turmoil condition such as Covid-19 pandemic. In this context, it is essential to investigate the internal migrant tourism entrepreneurship within the family involvement.

2.3 Embeddedness Theory and Family Embeddedness Perspective

In order to uncover the family embeddedness and involvement in internal migrant's tourism entrepreneurship intention, the study will employ embeddedness theory and family embeddedness perspective. The embeddedness approach has been widely used in researching migrant entrepreneurship. This theory implies that migrant entrepreneurs are affected by their embeddedness into a combination of crucial interplay between the social, economic, and institutional contexts where they establish their businesses (Barberis & Solano, 2018).

Among different forms of embeddedness, family embeddedness is the perspective focused the moderating role of family toward migrant entrepreneurship. Family embeddedness perspective strongly suggests the investigation on entrepreneur's ties with their family and other social entities. Family characteristics, transitions, resources, and values, as well as the social and economic context may affect the venture creation process and the subsequent business (details seen in Figure 1) (Aldrich et al., 2021).

However, the attention of the embeddedness approach and these related models has largely been on immigrant/external migrant, that is, migrants' embeddedness in the socio-economic and politico-institutional environment in new country of destination or at trans-national level (Bagwell, 2018). Not many publications have deep analysis for internal migrants who may also confront more challenges or catch more opportunities in comparison with their native counterparts. Hence, this study will contribute to the development of both migrant entrepreneurship and family business theories by employ embeddedness theory and family embeddedness perspective to explore the moderating role of family involvement toward internal migrant's tourism entrepreneurship intention.

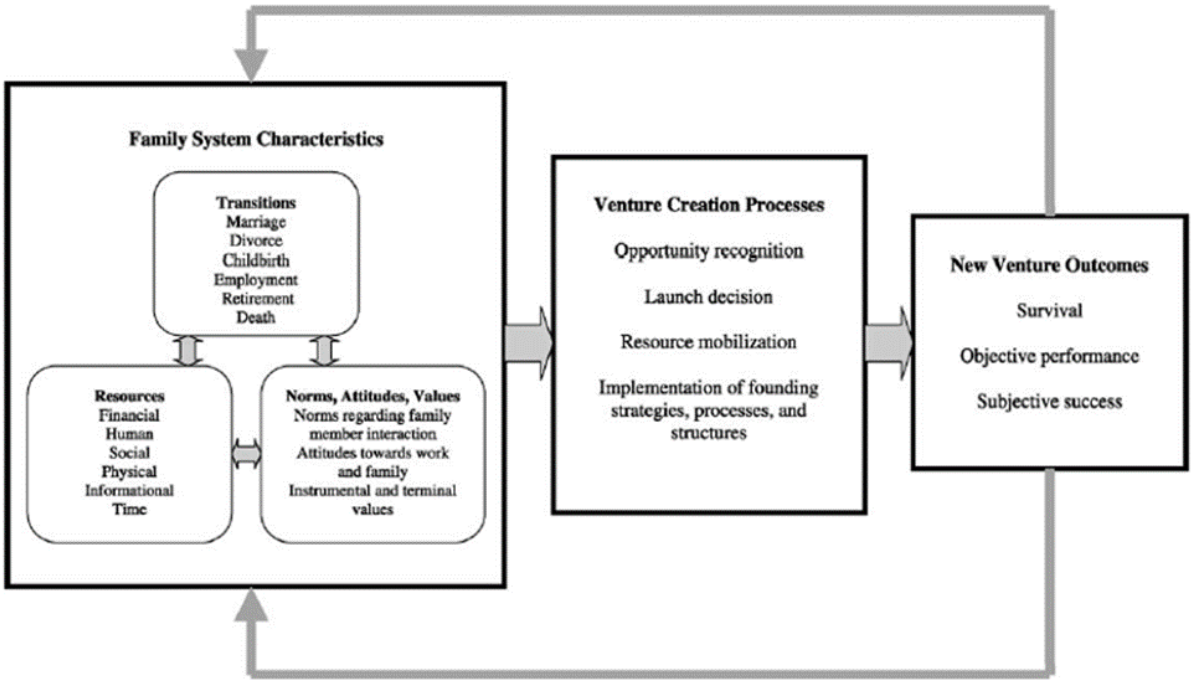

Fig. 1 – Family Embeddedness Perspective on Entrepreneurship. Source: Aldrich & Cliff (2003)

3 CONCEPTUAL MODEL AND HYPOTHESIS FORMULATION

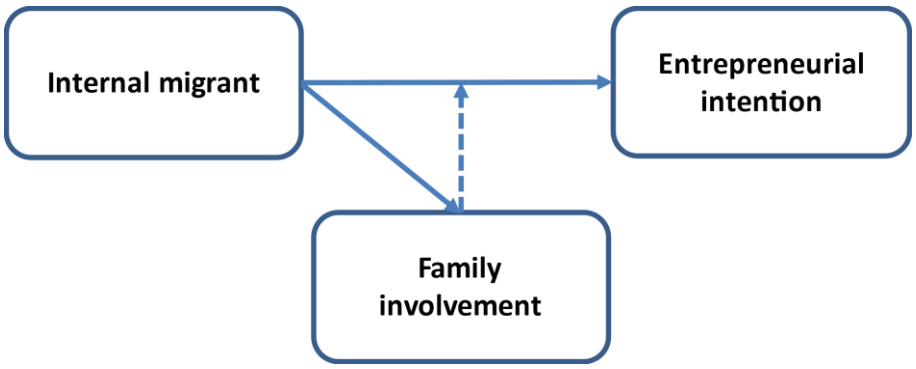

Fig. 2 – Conceptual Model. Source: own research

3.1 Internal Migrant and Entrepreneurial Intention

Results of many migrant entrepreneurship studies show that, in general, migrant-founded small businesses have lower levels of business survivability than their local counterparts, especially in the in turbulent context like the Covid-19 pandemic, when it is difficult to receive supportive sources (Li & Johansen, 2021; McAuliffe & Khadria, 2020; Etemad, 2018). Although the evidence for these challenges is mostly found from the results of studies with external or trans-national migrant businesses, the same impact could be expected for domestic migrant businesses because there are still differences in institutional regulations, business promotion policies culture between provinces, cities, and regions within a country. Hence:

H1: Compared with local counterpart, internal migrant has negative association with entrepreneurial intention.

3.2 Internal Migrant and Family Involvement

Besides, relating family involvement, local residents often have stronger family ties, including in business. They often have stable houses with relatives, families with many generations living in the vicinity. At that time, the trend is that entrepreneurial business activities of these local people may easily involve family under the form of family-owned business using the family labour force and having higher mutual trust. For the migrants, it is not easy to convince other family members to move to a new destination (Aldrich et al., 2021). Even if that happens, stabilizing the whole family is also a challenge in terms of costs. and logistics, as well as safety, health, and education factors. Thus:

H2: Compared with local counterpart, internal migrant has negative association with family involvement.

3.3 Family Involvement Among Internal Migrant Entrepreneurial Intention

However, if the migrants receive support from their family, the involvement may increase the intention of migrant on establishing entrepreneurial businesses. Much of the evidence for this positive effect has been found in studies on entrepreneurship among external migrants (Bird & Wennberg, 2016), and we predict that it also applies to internal migrants.

H3: Family-involvement increases internal migrant entrepreneurial intention.

4 METHODOLOGY

4.1 Qualitative Analysis

In the first stage, a combination of systematic literature review and in-depth interview technique would be applied to identify critical factors or interactions are missing from the model. Particularly, semi-structured questionnaires will be sent and personal interview will be made to 15 experts in tourism sector, using a purposive sampling approach. In more details, they are academia from tourism-relating universities; tourism management organizations experts; and local authorities from Department of Culture, Sports and Tourism Center for tourism development.

4.2 Quantitative Analysis

Next, the quantitative analysis through questionnaire survey (consisting of five Likert scale points) with +250 family business alongside the Partial Least Square Regression will be conducted. Test for Common Method Bias to identify probability of scale misinterpretation among the responses will be conducted through the Factor Analysis Module of SPSS by IBM. A close ended questionnaire with adapted items will be deployed in the sample space through online medium and intercept method.

Da Lat, a famous tourist destination located on the Lam Vien Plateau of the Central Highlands of Vietnam, was chosen as the site for the survey. Re-opening after the tourism industry was "frozen" due to the COVID-19 epidemic, the number of tourists coming to spring tourism, sightseeing and relaxation in Da Lat was more than 300,000, an increase of more than 566% compared to the Lunar New Year 2021 and increased by 15.4% compared to the Lunar New Year 2020. This place has been attracting a large number of migrants to develop tourism activities and would be suitable for the study’s purpose. The surveyed participants will be chosen randomly from the list of both local and migrant entrepreneurs provided by the local tourism association. The majority of respondents would be the owners/founders of relevant tourism business including hotels and homestays, travel agencies, souvenir shops.

5 EXPECTED CONTRIBUTION

Our research novel is to apply embeddedness theory on researching internal migrants, focusing on family embeddedness perspective in the context of tourism sector under the Covid-19 Pandemic. The paper expects to explore the challenges confronting internal migrant entrepreneurial intention in comparison with their native counterparts as well as the moderating role of the family involvement on their business intention and survival. Thereby, the study contributes to the expansion of the existing knowledge of migrant entrepreneurship and family business. Besides, our research's findings are expected to suggest beneficial implications for national government policy to focus more on encouraging internal migrant's tourism entrepreneurship.

A limitation we aware during the research implementation is that due to resource limitations, we are not able to obtain comparable results across multiple tourism destinations within the same country (Vietnam), as well as across different countries. This will imply the direction for upcoming research on further studying the impact of regional differences and macro contexts on family embeddedness and involvement in internal migrant's tourism entrepreneurship intention.

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FACTORS AFFECTING CONVERGENCE AND DIVERGENCE IN INTERNATIOANL MARKETING STRATEGY – A CASE STUDY OF ADECCO VIETNAM JOINT STOCK COMPANY

Giang Thuy Nguyen, Hanh Ly Thi My

Abstract

In international marketing, the key question is whether marketing activity should converge or diverge. It is crucial for multinational companies (MNCs) and many Vietnamese businesses looking to grow into international markets to know whether they should utilize globalized or localized advertisements. The goal of this study reports the results on the views of the executives and managers from the researched MNC in Vietnam on the factors determining their international marketing strategies. Using in-depth interview approach, we interestingly found that the marketing strategies of Adecco Company are highly variable among countries and affected by several factors such as the business environments, economic situation, and cultures. We also found that the marketing strategies in the researched MNC are more likely to diverge. Our results provide Vietnamese businesses the valuable implications on effective marketing strategies, which help them successfully extend their operations internationally in the years to come.

Keywords: *convergence, divergence, international markets, international marketing, Adecco company*

1 INTRODUCTION

The ASEAN Economic Community (AEC) was established in December 2015, bringing with it a plethora of opportunities and problems for Vietnamese businesses. The AEC is an initiative to transform the region into an area with free movement of goods, services, investment, skilled labour and capital. It has four main goals: a single market and production base, a competitive economic region, equitable economic development, and integration into the global economy (ASEAN, 2020). AEC has become a common concept in everyday life in Vietnamese businesses, and it has had a huge impact on how Vietnamese businesses operate. The AEC promotes trade among its members and increases trade and investment throughout the area. Along with some significant benefits to the country members associated with this process, such as more developed information technology, higher income per capita, cheaper goods and a larger range of choices for customers, higher living standards, and so on, it is believed that doing business in different countries has led the firms into two different directions of marketing strategies, which are convergence and divergence (Cheney et al., 2010). Therefore, the aim of this paper is to discuss the central issues associated with the factors determining the international marketing strategy of MNCs, and to look at the significance of these trends and how much rethinking and refocusing worldwide marketing strategy is required. Specifically, the study provides findings of an interview survey conducted at Adecco Company in Vietnam during the first quarter of 2022 which sought the opinions of the executives and managers about the different factors concerning their marketing strategies in different countries.

The following sections are as followed. Section 2 provides an overview of literature and hypotheses. Section 3 reports the methods and sample collection procedures. Section 4 presents the qualitative results, which is followed by the section 5: conclusion.

2 LITERATURE REVIEW

When a company intends to expand its business, it should consider if it can globalize its brand or if the brand should be localized according to the customers' needs and demands of particular countries or regions (Svensson, 2001). Since the 1980s, there has been a major preoccupation about the globalization of brands and the standardization of marketing practices (Sinclair, 2008). However, at the end of the 1980s, failures in global marketing caused that MNCs decided to retreat towards more market-specific approaches (Jones, 2000). Some market experts think that marketing strategy should be standardized to gain the benefits of economies of scale because they do believe we are from different countries in the world but conducting our business in the single marketplace. Cheney et al. (2010) hold that it has created forces which are transforming the world and making cultures increasingly similar. In other words, in spite of the existing differences between nations, it pushes societies and organizations to align themselves towards the same economic and technological structures.

However, on the other hand, some might argue that dramatic differences across cultures, religions do matter and thereby the standardized advertising which ignores local cultures may not be an effective way to succeed in global markets. Therefore, often more value can be created through the adaptation of the brand, its products, and marketing practices in order to suit a particular country or region, market segment and even ethnic groups, communities and individuals on a one-to-one basis (Kapferer, 2008). In addition, Douglas and Craig (2011) argued that as managers become more mobile and move across national borders from one country to the next, their outlook becomes more culturally diversified, sparking increased interest and sensitivity to culturally and economically diverse market opportunities. Cheney et al. (2010) state that firms doing business in different nations have caused a drive towards divergence if significant differences across cultures and nations are focused. This means if organisations want to enter into the global marketplace, it is necessary that their goods and services on a global basis should be differentiated to cater for specific audiences and this process is in other word defined as 'glocalization' (Svensson, 2001).

Economic integration has caused the convergence in every aspect of lives including international marketing across the globe. Nowadays, products and services are standardized and therefore they can be sold successfully in different marketplaces because no matter where people are, they are still willing to adopt products from other countries. The important point is that now people start to develop the same tastes, expectations and interests in goods available in the market. For examples, KFC, Coca-Cola, Pepsi and McDonald's have been warmly welcomed everywhere in the world that are the typical examples to illustrate the convergence of needs, tastes and lifestyles across the globe. Thanks to increasingly converging international consumers, Elinder (1965) and Fatt (1967) believed that global advertisers could make their operations more convenient through the use of standardized advertising campaigns. Also, with the help of new communication technologies, "there is convergence of art, literature, media availability, thoughts, religious beliefs, culture, living conditions, language and consequently advertising" (Onkvisit & Shaw, 1987). As a result, it is quite simple to understand why some international corporations are selling the same products or services in the same ways whatever markets they are in. The ways they promote themselves in one nation is pretty the same as how they appear in other countries. For instance, Frith (2006) gave the case of how Tommy Hilfiger launched a global advertising campaign for its cologne Freedom. The company had its advertisement illustrated by an American flag which is waved by a group that may be a political rally. Also, apart from the Tommy Hilfiger logo which is red, white and blue American flag, the name of the cologne - "Freedom" conveys the political freedom (Frith, 2006). In addition, Levitt (1983) believes that in order to be successful, those worldwide businesses should have a "common brand name, packaging and communications" as part of their global marketing

strategies. Therefore, wherever people go, they still are able to recognize Coca-Cola, Mac Donald, and KFC easily because those above businesses always have products with the same logos, slogans and even developing similar advertising messages to the variety of consumers on earth as well.

But why does standardized advertising strategy sound an effective approach to apply for those who wish to expand their business beyond their borders? Some potential benefits which this approach might bring to us are being discussed. First, Morris and Pai (1997) pointed out the huge costs of commercial production will be saved if the company adopt it successfully. Second, this identical advertising strategy enables the company to totally control its brand name and image (Morris & Pai, 1997). Not just the global needs, tastes and lifestyles are becoming increasingly converging, the cultures and values are regularly shared and exchanged among countries within the globe. With the support of advanced information technology liked the internet; worldwide suppliers, manufacturers, distributors, agents, service providers and consumers have a great opportunity to get closer together. Since everyone around the world can access exactly the same kind of information, receiving similar latest news or messages regardless of distance, we begin to want and desire all the things we have seen or heard about just like anywhere else (Levitt, 1983). Thus, this is an extremely good chance ever for advertisers to take advantage of homogenised marketing methods. Perhaps in their opinions, it seems that there is no point of making any changes or modifying something in terms of marketing campaigns when entering different markets because people now share the same values, having similar expectations on products and services which are on the markets. In general, they just simply keep the same messages, launching the similar distribution networks, identical communications, exactly like the way they advertise themselves in their home countries. "Just do it" of Nike's slogan or "Come alive with Pepsi" of Pepsico are very popular not only in America but also across the globe. Also, Graddol (1997) suggests that as a result of economic integration, the huge international movement of labour encourages the convergence of languages as people are likely to share similar languages when they are required to communicate directly with one another in every international business transactions every day. Some languages such as English are getting so popular and being widely spoken by many groups and individuals in the world. This situation makes it easy for marketers to approach foreign buyers since many people can speak some certain common and popular languages. Therefore, as can be seen, language is no longer a barrier in international communications, then marketers and buyers are more likely to understand each other better. Frith (2006) stated that multinational brand names are generally in English and although when campaigns are translated into local languages, English words and slogans often are incorporated. He also gave a typical example, which is there is 35 percent of the population that speaks enough English to be able to follow English slogans like Nike's "Just do it" or Apple's "Think different" or over 85 percent of all internet websites are constructed in English.

However, it is convinced that when expanding commercial empires, in order to survive, organisations must cater to local audiences and meet local needs. Because the business environments, cultures, and economic situation are still different among countries despite a number of similarities do exist; there should be some pressures and forces which create more divergent content. Why is it so? From foreign traditions, point of view, customs, values to behaviours vary considerably from country to country, thereby it affects the business of every international firm in all aspects comprising contract negotiations, production operations, marketing decisions (Griffin & Pustay, 2019). Marketing is not an exception. It has to do with many things consisting of conducting market research, understanding the target markets, getting to know buyer behaviours which are influenced by the cultures (Griffin & Pustay, 2019). For example, it was discovered by market researchers that English Canadians are fond of soaps

which promises cleanliness while French Canadians prefer pleasant or sweet-smelling soaps. As a result, Procter and Gamble launched an English advertisement which emphasizes the soap's deodorant value and another French advertisement focuses on the soap's pleasant aroma (Griffin & Pustay, 2019). Hence, those advertisers who do not understand the value paradoxes in global cultures and think that the world is becoming one culture with similar values are most likely to fail in overseas markets except when they can offer particular unique and distinctive kinds of products that certain markets wish for. In fact, some global companies have experienced negative consequences because of cultural ignorance.

Besides, "Cultural diversity" is the cause of "different advertising styles in different countries" (Mooij, 2021) as it influences marketing and advertising at all levels: not only consumer behaviour, research methods; but also, philosophies of how advertising works, advertising strategy and concepts as well. In other words, advertising styles vary among countries. An example is whilst British beer advertisement mostly used humour appeal; American beer relied on emotional and sex appeal (Mooij, 2021). Likewise, language is also one of aspects of culture. Thus, even if some languages have seemed to be the predominant ones which are used widely in international markets, local language has to be taken into account for the reason that "people live their lives in their own languages". And in case a particular company is going to take the export market seriously, it had better use marketing techniques in the language of that market because once concepts or messages developed in one culture are transported to another culture, "they lose meaning and are less effective" (Mooij, 2021). Why is one standard message not sufficient for all markets? The issue is that "People in different countries not only speak different languages but their languages also represent different world views" (Mooij, 2021). Thereby, translations are just not good enough to reveal those "different worldviews, different ways of thinking and different intellectual styles" (Mooij, 2021). A good example is in Japan, the word for "heart" associates with "warmth", not necessarily with "love" as love is not expressed the same as in the western world (Mooij, 2021). So, the lesson for global marketers is "marketing always takes place in the language of the target market". That is to say, marketers have to appreciate the local language and develop advertising campaigns in the language of their target markets whether the means of communication with consumers is advertisements, articles in newspapers, magazines, or on the radio, television, or the internet. That is the only fastest and the most effective way to promote their products as well as drawing attention from consumers in the potential marketplaces. There are some interesting examples of businesses' failure when dealing with various markets without taking language into consideration. American Motors tried to market its new car which is called the Matador based on the image of courage and strength but it turned out unpopular in Puerto Rico since it means "killer". Therefore, that explained for the reason for the needs to go local or in other word 'glocalisation' to be effective when doing business globally (Svensson, 2001).

3 METHODOLOGY

The Adecco Group is a Fortune Global 500 Company and a pioneer in human resources services around the world. The Adecco Group provides clients and colleagues with flexible staffing and career tools. Since its inception in Vietnam in 2011, Adecco Vietnam has built a network and experience to help clients establish effective teams. An interview schedule containing several open-ended questions which are designed to collect more in-depth information and answers. This study was carried out for 3 different departments and interviews were conducted over a one-month period towards the end of February, 2022. The study was directed to those holding the job position of executives and managers in the three departments which are Recruitment Services, Payroll & Staffing, and Human Capital Solutions. In each department, the functional head also participated in the survey. The interviews were taped and later transcribed.

In general, there are 24 executives and managers participating in the interviews, on either individual or group basis. Responses for all questions are limited to the context of Adecco Company but experiences of participants at other organisations were provided. Answers for questions relating to the marketing strategy were in the context of assessment of products, pricing, promotion and distribution that the company offers in Vietnam.

4 QUALITATIVE REULTS AND DISCUSSION

The question raised here is that why some services offered by Adecco in Vietnamese market are different from the ones in other countries. The answers can be related to the differences in business environment, national cultures and economic situation among countries. Prior literature indicates that the differences in marketing strategy might be justified by marketing infrastructure, competition, political, organisation and managerial (Ryans & Ratz, 1987; Jain, 1989). Nonetheless, no research to date has found the relationship between those factors and the marketing strategy in the context of Adecco Company.

The findings of the research show that, to some extent the business environment, the national culture and the economic situation are among imperative factors which can explain for the variations in the international marketing strategy. This is in line with the results of Theodosiou and Leonidou (2003). Indeed, results for business environment characteristics indicate that variations in the design of services, promotion and prices are found to be the significant influencing factors in convergence or divergence of the marketing strategy. Most of the answers for the question 'which factors influence the design of company's services, promotion and prices offered to customers' placed the emphasis on the business environment which makes the company adapt their strategies to the locals.

In addition, with the two questions about 'does local culture have impact on the company's promotion strategy', we found that the majority of people answered that the cultural factors influence significantly with the promotion strategy. In Vietnam, culture plays a vital role in all aspects of life so that any advertisements are highly relevant to the norms, value of the nation. This is quite consistent with the findings of Lipman (1988). All of the items people buy, the qualities they value, and the principals whose opinions they accept are all culture-based choices.

Unsurprisingly, economic factors are among the ones affecting the marketing strategy of Adecco Company with most of the answers say 'yes' with the question 'do you consider economic factor when designing products' prices?'. In fact, poor economic means may prevent masses in developing country like Vietnam from buying the variety of products that the consumers in developed countries consider essential. Thereby, to bring such expensive products and services within the reach of the middle class in developing countries, for example, the products or services must be appropriately modified to cut costs without reducing functional quality (Jain, 1989). This in line with prior literature (Jain, 1989).

Discussion: because of the wide range of market conditions that Adecco is operating, developing a globally integrated strategy is unlikely. As a result, the company can no longer concentrate on building a consistent worldwide integrated marketing strategy to gain synergies through the transfer of services, skills, expertise, and learning across markets. Rather, the strategy must be reinvented and reengineered in order to set direction, seize opportunities, and manage operations in a wide range of multiple, very different markets around the world, where conditions differ significantly from those in which Adecco has traditionally functioned in the past. Adecco's expansion into an increasingly broad and diversified range of foreign markets means that it must deal with marketing in a variety of distinct environmental and contextual market situations. Economic aspects, such as wealth and financial stability, as well as cultural factors, such as ethnic variety, age distribution, and religious preferences, distinguish countries.

All of these aspects have an impact on the creation of marketing strategies, possible market possibilities, and target segments, implying that customizing strategies to local market features and customer interests, preferences, and behaviour is a must.

5 CONCLUSION

The results of this research indicate that marketing strategy is highly divergent although one standard message of a certain product for the worldwide market may reduce cost thanks to the economies of scale, that message still cannot work well across the globe. The Adecco company is facing an increasingly complicated range of scenarios as it grows its activities across a much greater geographic basis. This makes developing a coherent and integrated global market strategy challenging. In addition, the point is that it is obviously unable to carry all its meanings from one culture to another because the varieties of culture hold different values, beliefs, etc. Most of all, the culture of the target consumers should be reflected in ads and therefore, many adaptations in Adecco are needed so that advertisements are relevant to that culture. As a result, no matter how strong the effects of globalisation and economic integration are, the marketing strategy of Adecco is more likely to become diverging. And also, being sensitive to the economic situation and business environment has developed into the popular trend of global marketing and become the key to international business success of Adecco. Thus, for the managers of Vietnamese enterprises that know the secret of getting involved in this trend are the ones that are most likely to succeed in the global market.

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INTERREG V-A SLOVENSKÁ REPUBLIKA ČESKÁ REPUBLIKA SK-CZ 14-20 EURÓPSKA ÚNIA EURÓPSKY FOND REGIONÁLNEHO ROZVOJA SPOLOČNE BEZ HRANÍC BÍLÉ - BIELE KARPATY ŽILINSKÝ SAMOSPRÁVNY KRAJ

FOND MALÝCH PROJEKTOV

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TOTAL QUALITY MANAGEMENT IN THE CONTEXT OF INDUSTRY 4.0: A THEORETICAL FRAMEWORK

Thi Anh Van Nguyen, David Tuček, Thi Thu Huong Nguyen

Abstract

Industry 4.0 is transforming from traditional manufacturing to automotive production, using the internet of things, big data, artificial intelligence (AI), and smart factory. It brings the organisations both challenges and opportunities. Total Quality Management (TQM) is a critical philosophy that helps enterprises achieve success and a competitive edge. Out of the context of the Fourth Industrial Revolution, TQM practices need to adapt to an uncertain and changing environment. This research uses systematic literature review (SLR) methodology to explore the latest literature about TQM practices in the context of Industry 4.0. From previous results, it was made a theoretical framework of TQM practices in Industry 4.0 based on socio-technical system theory. The main components of industry 4.0-TQM integration are defined to contribute quality management literature. This study also provides the framework for academics to investigate further research and for practitioners apply the Quality 4.0 model to achieve sustainable development in the long term.

Keywords: *TQM, Industry 4.0, SLR methodology, socio-technical system theory*

1 INTRODUCTION

Industry 4.0 (the Fourth Industrial Revolution) has some unique features such as big data analytics, autonomous robots, simulation, horizontal and vertical system integration, the industrial internet of things, cybersecurity, the cloud, additive manufacturing, and augmented reality (Cimini et al., 2020; Chiarini, 2020; Bag et al., 2020). This revolution affects many fields in the competitive environment, including quality management. Total Quality Management (TQM) is the crucial management philosophy of many enterprises to improve and enhance their competitive advantage. TQM is a crucial factor that helps enterprises to achieve successful performance (Jaca & Psomas, 2015; Abbas, 2020; Pertusa-Ortega et al., 2021). In technology development toward Industry 4.0, TQM practices have changed to react to different risks and opportunities. Therefore, finding the main components of TQM practices in Industry 4.0 is essential. Some authors have attempted to find the main factors of TQM practices in the context of Industry 4.0; however, they are not connected with any theory (Chiarini, 2020). This study aims to use socio-technical system theory to explore the main factors of TQM practices in the context of Industry 4.0. The authors use a systematic literature review methodology to answer the two questions below.

RQ1: What are the differences between TQM application in the context of Industry 4.0 and former TQM models?

RQ2: What are the main pillars of TQM framework in the context of Industry 4.0?

The main objective of this research is to build a theoretical framework of TQM practices in Industry 4.0 based on socio-technical system theory. This study will provide scholars with a framework to analyse the TQM practices, and it will provide the practitioners with a TQM model that applies in organisations to adapt to changeable environments in the context of Industry 4.0.

2 THEORETICAL BACKGROUND

2.1 Industry 4.0 definition

Industry 4.0, also called the Fourth Industrial Revolution, has introduced the intelligence digitalisation and integration of information technologies to build a smart factory where humans, machines, and products communicate with each other via both physical and virtual means and can contribute to increased sustainability (Bag et al., 2020; Neumann et al., 2021). There is a long development process of the Four Industrial Revolution (see Figure 1).

The First Industrial Revolution took place in 1760-1820 when people realized that they could use water power and steam power to change from hand-making production to using machines, thus called 'mechanization.' The term The Second Industrial Revolution is used to describe rapid industrialisation from the end of the third quarter of the 19th century to the 20th century. At that time, our society started to use electric power for mass production and assembly lines powered by electricity, thus called “electrification”. The Thirst Industrial Revolution began in the 1950's and it was followed until the 1970s by so-called “digitisation”. People started to use artificial digital logic circuits and computers, cellular phones, and the internet to produce autonomously. The latest Fourth Industrial Revolution developments make use of cyber-physical systems, including big data analytics, autonomous robots, simulation, horizontal and vertical system integration, the industrial internet of things, cybersecurity, the cloud, additive manufacturing, and augmented reality (Chiarini, 2020; Zhou, Song, & Cui, 2020).

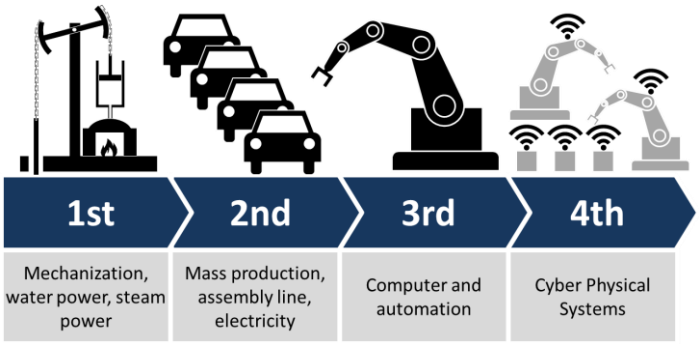

Fig. 1 – The four “industrial revolutions”. Source: Roser (2015)

2.2 Total Quality Management (TQM) definition

TQM is the business revolution in the industrialised world (Miller, 1996). TQM provides principles, tools, and methodologies whereby top management and employees in the organisations gain stakeholder satisfaction (Miller, 1996; Zhang et al., 2020; Alshourah, 2021). Besides, TQM encompasses every aspect of the business or organisation, not just the systems used to design, produce, and deploy its products and services. This system includes all support systems such as human resources, finance, and marketing. TQM involves every organisation's function and level, from top to bottom (Goetsch & Davis, 2013).

While some researchers define TQM as quality management standards such as ISO 9001, ISO 9004, some studies use business excellence models (Baldrige, EFQM, and Deming Prize) that present TQM in their works. ISO 9001 sets out the criteria for a quality management system. This standard base on several quality management principles, including a strong customer focus, the motivation and implication of top management, the process approach, and continual improvement. ISO 9004 gives guidelines for enhancing an organisation's ability to achieve sustained success and provides a self-assessment tool to review the extent to which the organisation has adopted it (ISO, 2021).

According to Sader et al. (2019), the main part of TQM includes quality control, quality assurance and Total Quality Management. The TQM was also integrated into Industry 4.0- (see Figure 2). Quality control focuses on the product by using inspection to find the defective product as well as practising some tools. Quality assurance not only guarantees quality products but also enhances stability process. Total Quality Management is a management philosophy that embraces all quality issues of product, process, and system.

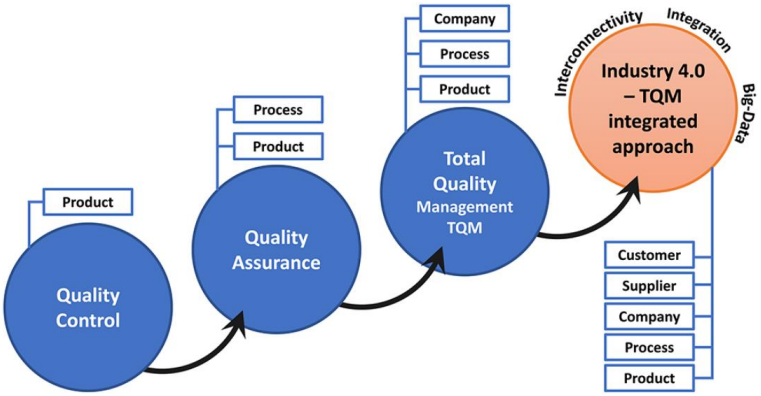

Fig. 2 – The development of TQM. Source: Sader et al. (2019)

3 METHODOLOGY

In this research, the authors used a systematic literature review (SLR) to collect and analyse studies that explore Total Quality Management in the context of Industry 4.0. SLR is one of the most used literature review methodologies that employ a systematic process. According to Cruz-Benito (2016), this methodology can be structured in five stages.

Stage 1: Define the research question

RQ1: What are the differences between TQM application in the context of Industry 4.0 and former TQM models?

RQ2: What are the main pillars of TQM practices in the context of Industry 4.0?

Stage 2: Define criteria: To explore the framework of TQM in the context of Industry 4.0, the authors focus on keywords such as Total Quality Management, Industry 4.0, Quality 4.0. The inclusion criteria are all quality methods, including lean, lean six sigma, six sigma, and quality tools (Statistical Process Control).

Stage 3: Search in scientific databases and extract relevant data: The authors searched in the Web of Science (WoS) database that is the best scientific database recognised by scientists.

Stage 4: Assess the quality of the results (can iterate the process): All of the studies were assessed carefully by the inclusion and exclusion criteria. In addition, the authors excluded the papers that are not relevant to quality management content.

Stage 5: Analyse, discuss and propose from the results: The authors had to search literature which was investigated in terms of Industry 4.0 and quality management integration. Based on these facts, the research suggests quality management system that adapts the industrial 4.0 and digital context.

4 RESULTS

Researchers searched papers from 2010 to 2021 on the Web of Science (WoS) database three times. Firstly, authors found the keyword "QUALITY 4.0". Secondly, authors used the keywords "INDUSTRY 4.0" AND "TOTAL QUALITY MANAGEMENT". Finally, the keywords are "INDUSTRY 4.0" AND "QUALITY MANAGEMENT". Table 1 shows the results after three rounds of searching.

Tab. 1 – The number of papers from the WoS database. Source: own research

Keywords	Article	Proceedings paper	Review	Total
Quality 4.0	15	3		18
Industry 4.0 + Total Quality Management	5	4	3	12
Industry 4.0 + Quality Management	36	26	4	66

Round 1: Authors read all papers' titles, keywords, and abstracts to classify them based on inclusion and exclusion criteria. Researchers excluded papers that focus on gaining specification products such as electrical products, medical products, warm-season turf-grasses (in the agriculture field), aircraft fuselages and wind turbine blades (device), CNC machinery. The authors also excluded the papers that are not relevant to quality management content. Authors kept papers focusing on Total Quality Management and we employed quality methods, including lean, lean six sigma, six sigma, and quality tools (for example, Statistical Process Control). The results in Table 2 follow.

Round 2: Using the results of round 1, the authors compiled all the papers into one file. If there were similar papers, researchers kept only one. Although there are quite different keywords, many matching documents were present. The result of this round was 53 papers.

Tab. 2 – The number of papers for two assessment rounds. Source: own research

Keywords	Quantity	Round 1	Round 2
Quality 4.0	18	10	53
Industry 4.0 + Total Quality Management	12	11	
Industry 4.0 + Quality Management	66	45	

Although authors researched papers from 2010 to 2021, the results show that these studies were done since 2016 when term Industry 4.0 became popular. Almost all publications between 2016 and 2018 were conference papers, and there is a significant increase in the number of articles from 2019 in this field (see Figure 3).

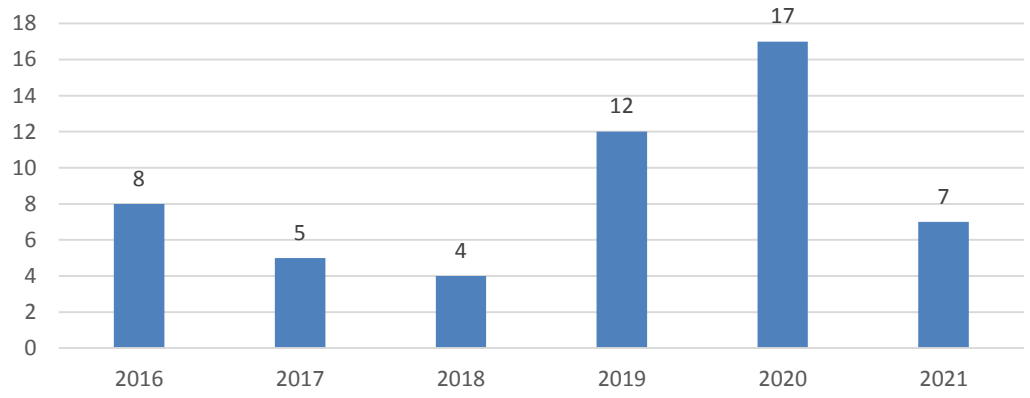

Fig. 3 – The number of papers according to years. Source: own research

Some authors attempted to find the main factors of TQM practices in the context of Industry 4.0; however, they are not connected with any theory (Chiarini, 2020). Moreover, Chiarini (2020) suggested that in future studies attention should be paid to research into the integration

of ISO 9001, Six Sigma define-measure–analyse–improve–control (DMAIC), quality function deployment (QFD), and failure modes and effect analysis (FMEA). While sustainability in the quality management field came onto the literary scene in 1996, digitalisation is currently absent from the scholarly QM literature (Carnerud et al., 2020).

4.1 TQM application in the context of Industry 4.0 versus former TQM models

The quality management approach started by inspecting the final product during the First and the Second Industrial Revolution. After that, the inspection was expanded to check inputs (materials, machines), processes, and outputs (semi-finished products, final products). In this stage, statistical process control (SPC) was introduced. Engineers use some tools such as a checklist, Pareto chart, Cause-and-effect diagram, Stratification (Flowchart/Run chart), Control Charts, Histogram, Scatter Diagrams. These tools were used for problem-solving and process improvement by collecting and interpreting data to provide the basis for decision making. During the Third Industrial Revolution, the SPCs developed powerfully and became a premise for developing many other techniques such as Design of Experiments (DOE) and Robust Design Methods. SPC can be used to control different factors, but which factor should be controlled? Design of Experiment used to solve this question. It is a special way to improve a process by discovering cause and effect relationships. In the 1980s, Genichi Taguchi found that most problems could be traced to a product or process design. Taguchi utilised DOE in a very smart way and developed the Robust Design method. The method enhanced the design of the product/process to achieve quality product by "do right at the first time".

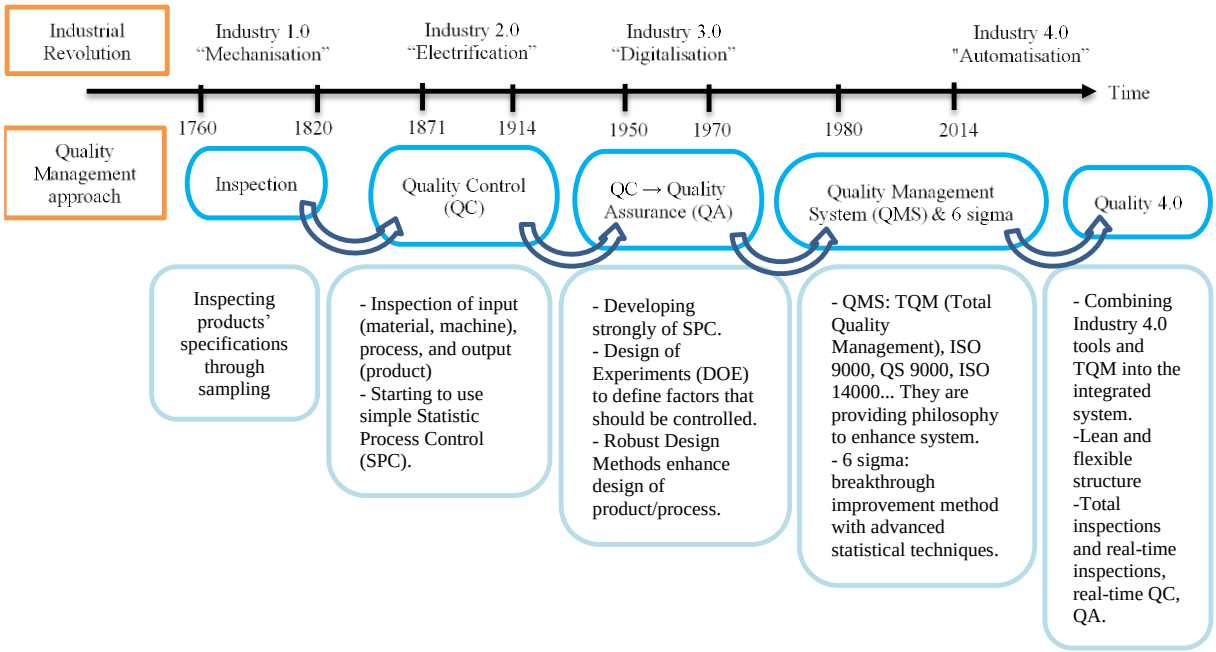

Fig. 5 – The process of Quality Management approach. Source: own research

In 1990's, there was a strong formation and development of Quality Management System (QMS). The concept of Total Quality Management (TQM) is known as a comprehensive philosophy. The International Organization for Standardization (ISO) launched the first ISO 9001 standard in 1987. This standard provides a model to follow when setting up and operating a management system to improve the quality of their products and services and consistently meet their customers' expectations. They also brought out ISO 14001 standard- environmental management system in 1996. This standard requires practical tools to manage their environmental responsibilities. In addition, a famous standard- QS 9000 was a quality standard

developed by several heavy truck manufacturers in the United States in 1994. QMS provides a philosophy to enhance the system. They provide a framework, not any tools or statistical technique. On the other hand, a breakthrough improvement method with advanced statistical techniques was introduced in 1995. The Six Sigma method provides organisations tools to improve the capability of their business processes. This increase in performance and decrease in process variation helps reduce defect reduction and improvement in profits, employee morale, and quality of products or services.

During the Fourth Industrial Revolution, TQM combined Industry 4.0 tools with an integrated system- "Quality 4.0". Industry 4.0 provides cyber-physical systems, including many tools such as big data analytics, autonomous robots, simulation, internet of things, and AI. Thanks to special characteristics, Quality 4.0 has many different features compared with former QM models. Quality 4.0 inspects the whole product instead of samples by fast information technology (IT) equipped with efficient inspection tools. Organisations also can gain real-time inspections, quality control, and quality assurance. Customers can design products to support customisation of the individual product. In Industry 4.0, quality experts and data scientists merge into one profession, 'data & quality scientist'.

4.2 Industry 4.0-TQM integration

Industry 4.0 has unique features such as big data analytics, autonomous robots, simulation, horizontal and vertical system integration, the industrial internet of things, cybersecurity, the cloud, additive manufacturing, augmented reality. TQM models integrate these features to enhance the ability to anticipate and react to different risks and opportunities. Some studies focus on finding the main factors of TQM practices in the context of Industry 4.0 (see Table 3).

Tab. 3 – The main factors of TQM practices in Industry 4.0. Source: own research

Authors	The main factors	Meaning explanation
Asif, 2020	Mindful QM	Mindfulness is crucial to promoting cognitive engagement in the workplace. It allows employees to control their motivation and behaviour, and they are better self-leaders, thus, reducing the need for external workers.
	Intellectual capital management	In the context of Industry 4.0, QM model not only focuses on human resources management but also addresses social and intellectual capital management.
	Making quality predictions from big data	QM models use artificial intelligence (AI) and large databases to build quality parameters and manage product/service quality.
	Lean organisational structures	QM models need to develop, maintain, and manage lean structures based on real-time data and maintain digital records.
	Managing networked firms in business ecosystems	QM models use the highly synchronised information system to coordinate value chain to produce products/services collectively.
Hyun Park et al., 2017	Mass customisation	In the mass customisation society, QM focuses on the speed of design, production, and delivery to satisfy customers.
	Quality responsibility	QM find maximised quality and safety in all product and service characteristics based on innovative technology and intelligent computation. Responsibility for quality in the industrial revolution is shown by brand quality and service quality.
	Open quality	"Open Quality" system is a new quality strategy in which all product and service quality characteristics are designed, produced, marketed, and sold based on open and transparent approaches. The system combines a comprehensive approach including speed, creativity, data analytics, and AI for meeting dynamic consumer requirements.

	Multiway flow of QM	QM becomes possible by data-oriented multiway interactions across the five stages: plan, design, production, marketing, and sales. These stages diagnose and feedback with the help of Big Data, AI, IoT, etc.
	Team creativity	Given the prominence of design quality in Industry 4.0, excellent creative thinking will have a greater emphasis on team and QM activities.
	Total inspection	Sampling inspection at the production stage disappears because of fast information technology (IT) equipped with efficient inspection tools.
	Data scientists as quality experts	In Industry 4.0, quality experts and data scientists will merge into one profession, 'data & quality scientist'.
Fundin et al., 2020	System perspectives applied	QM addresses systems thinking and strategic issue for company owners and customers by involving them in the improvement activities.
	Stability in change	QM has to develop the organisation's ability to handle new external forces while maintaining stability and handling the internal processes.
	Models for smart self-organisation	QM model enables and supports self-organisation in the face of increasingly complex and challenging situations.
	Integrating sustainable development	QM model needs to link quality and sustainability and develop operations more sustainable to achieve economic, social, and ecological sustainability.
Sader et al., 2019	Customer focus	Demand responsiveness is improved by intensive quality control and quality assurance practices. Industry 4.0 supports customising individual product, and provide a smart prediction of market needs.
	Leadership	Industry 4.0 features (such as "Vertical, Horizontal, and End-to-End integrations", Enterprise Resources Planning (ERP) systems, Big-Data analysis) add to QM leadership, including smart allocation of resources, high coordination among the organisation, and practical evaluation for results.
	Engagement of people	Industry 4.0 tools help improve communication and collaboration from connectivity features and social networking, facilitating innovation and sharing ideas.
	Process approach	Industry 4.0 will support the transparency of business and production processes; facilitate tracing production bottleneck, defects' sources, and minimise production cost; provide accurate information about processes (time, risks, resources, critical constraints) among all aspects of production to help the planning level of key processes maintains continuity and efficiency; simulates the possible production scenarios according to dynamic production parameters.
	Improvement	Industry 4.0 features such as AI and machine learning will enable the industrial system to interact dynamically with customer demand and predict early machine failures or defective products. QM system can improve learning improvement and enhance the ability to anticipate and react to different risks and opportunities.
	Evidence-based decision-making	Based on Big-Data, AI, and Cloud Computing, Industry 4.0 provides accurate data and information to support real-time monitoring, measuring, and determining its performance. Therefore, the manager can predict early failures and make early decision making.
	Relationship management	Horizontal, Vertical, and End-to-End integration, and the effective communication and collaboration tools between all stakeholders, and modern communication systems under the umbrella of Industry 4.0 provided a significant advantage in terms of relationship management with business partners.
	Quality assurance	Big-data analysis, smart machines, and smart factories will collect real-time data generated during production, transform it into friendly useful information to define and eliminate the root causes of production defects, and send early notification for predictive maintenance in advance to avoid downtime or system failure.
	Quality control	Industry 4.0 will provide intelligent quality control systems and real-time quality inspection.

4.3 The theoretical framework of TQM bases on socio-technical system theory

Socio-technical system theory is used widely to explore Industry 4.0 (Davis et al., 2014; Davies et al., 2017; Cimini et al., 2020; Sony & Naik, 2020; Schiele et al., 2021). The scholars have confirmed the appropriateness of this connection. Following that, the authors built a theoretical framework of TQM in Industry 4.0 based on socio-technical system theory (see Figure 4).

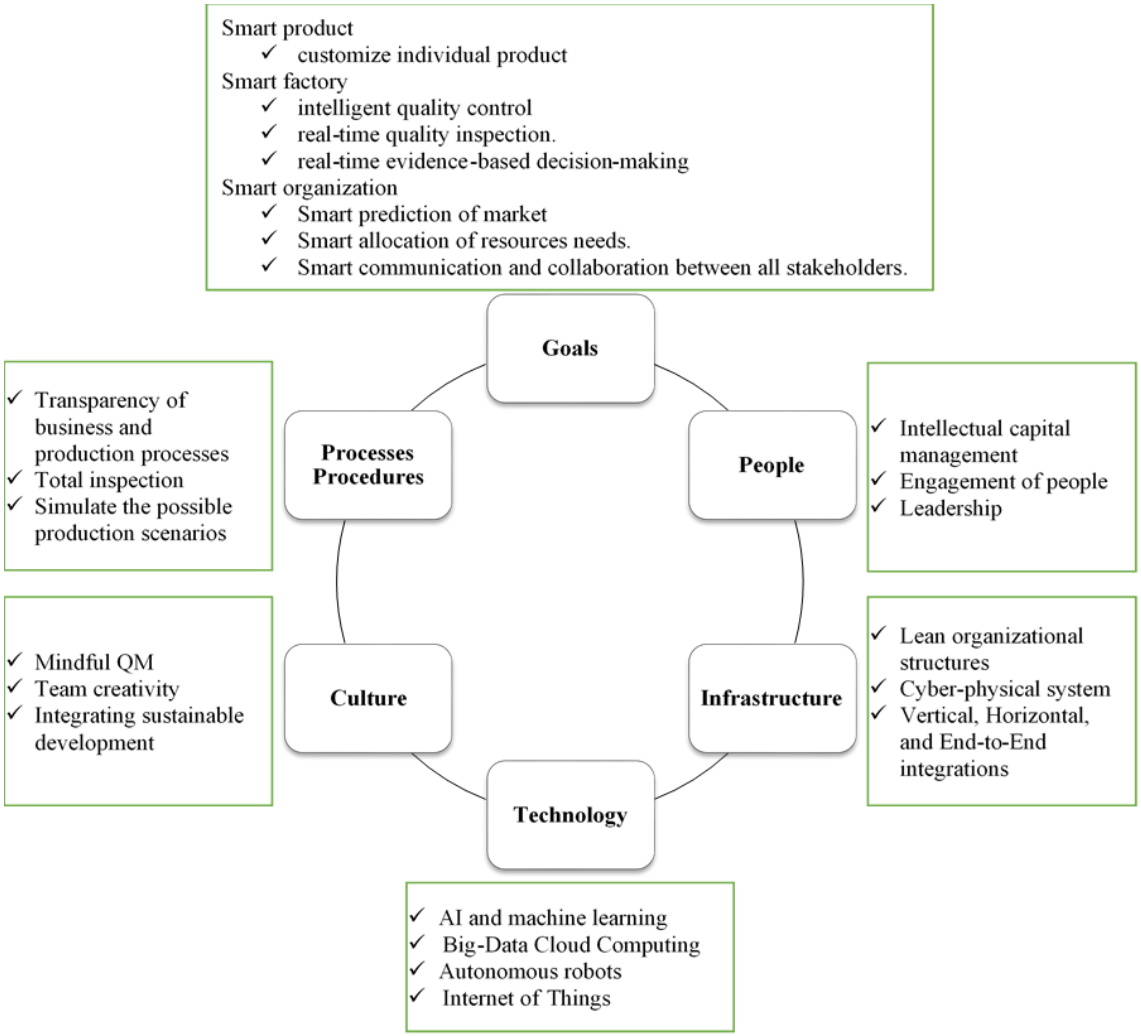

Fig. 4 – The theoretical framework of TQM in Industry 4.0. Source: own research

4.4 The main pillars of TQM practices in the context of Industry 4.0

Based on the theoretical framework of TQM in Industry 4.0, the authors introduced five main pillars of Quality 4.0 (see Figure 5). There are two background pillars, including technical factors and social factors and three vertical pillars that are the place to build a Quality 4.0 house, including smart organisation, smart factory, smart product.

Technical factors: Quality 4.0 model uses the tools in Industry 4.0 such as AI and machine learning, Big-Data Cloud Computing, Autonomous robots, internet of things, Cyber-physical system.

Social factors include human factors as well as cultural organisation. In Quality 4.0, intellectual capital management is emphasised because Industry 4.0 requires a set of skills and maintaining a repository of these skills is essential. Besides, Quality 4.0 also needs the engagement of people and leadership as the traditional TQM. However, Industry 4.0 tools help improve

communication and collaboration from social networking. People are not only connected face to face but also communicate effectively online in virtual space. The highlight of Quality 4.0 is the mindfulness that encourages the quality thinking of individuals. It is crucial to promote cognitive engagement in the workplace. Moreover, Quality 4.0 links quality and sustainability and development operations in a more sustainable way to achieve economic, social, and ecological sustainability.

Smart organization: If the traditional TQM is large and cumbersome system with many procedures, Quality 4.0 towards lean organizational structures to adapt with changed environment. However, with the powerful tools of Industry 4.0, this model can facilitate collaboration between all stakeholders regularly and effectively. Especially, quality experts and data scientists will merge into one profession, "data & quality scientist".

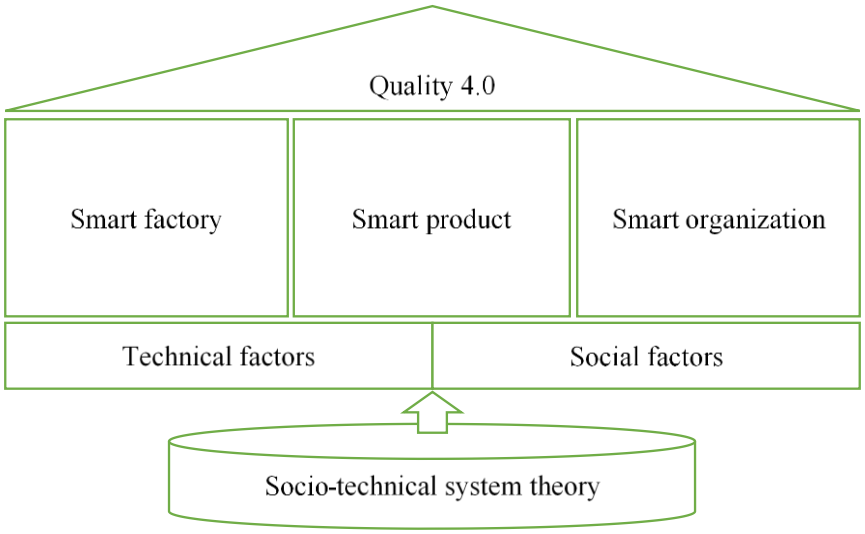

Fig. 5 – The main pillars of Quality 4.0. Source: own research

Smart factory: Quality 4.0 provides intelligent quality control systems and real-time quality inspection. Sampling inspection will be replaced by the inspection of all products. Quality 4.0 allows accurate data and information to support real-time monitoring, measuring, and determining its performance. Therefore, the manager can predict early failures and make early decision making. Based on AI and machine learning, the industrial system can interact dynamically with customer demand and predict early machine failures or defective products.

Smart product: Industry 4.0 provides tools to give a smart prediction of the market and customise individual products. Quality 4.0 finds maximised quality and safety in all product and service characteristics based on innovative technology and intelligent computation.

5 DISCUSSION

While traditional TQM focuses on standardisations, reduces variances to gain process stability and Industry 4.0 provides many tools and technology, the role of humans in the system seems to be mute. The framework base on socio-technical system theory will solve the issue. The socio-technical system encourages employees' empowerment, such as increasing individual and team self-control. From that, it motives flexibility, adaptability, and innovation. Socio-technical systems focus on internal resources by improving employees' productivity and building organisational culture that encourages creativeness and innovativeness. The framework of Quality 4.0 bases on the socio-technical system theory that was explored to provide a new concept to investigate.

Traditional TQM system open focus on external management than internal management. Many organisations apply TQM for customer requirements. For internal management, TQM emphasizes control process, reduce defective products and cost to gain financial performance. Although typical TQM mentioned leadership commitment, employee involvement, and human resource management, the effectiveness of human factors in this system is not high. Many authors discuss one reason is traditional cumbersome and bureaucratic TQM. The study explores the Quality 4.0 model, which encourages employees and workers' flexibility to increase individual and team self-control and motivates adaptability and innovation in organisational culture. From that, it will improve their environmental sustainability by focusing on human engagement and team-based approaches. This framework also notes the design of jobs and ways of organizing work that helps to improve work experience for employees and gain effective systems. The integration of social and technical approaches in the model is sustainable background for organisation development.

Social aspects of Quality 4.0 model capture the people who work in the organization and how they interact with each other. It is including intellectual capital management, communication and collaboration from social networking, the mindfulness that encourages the quality thinking of individuals. It also mentions engagement of people and leadership as the traditional TQM, but the addition is open communication between workers and managers such as information sharing, encouraging bottom-up open communication, two-way communication flows.

Technical aspects are integrating between tools in Industry 4.0 and techniques of typical TQM such as quality function deployment, failure mode and effect analysis, statistical process control. The tools in Industry 4.0 include AI and machine learning, Big-Data Cloud Computing, Autonomous robots, internet of things, Cyber-physical system.

The combination of social and technical aspects in the Quality 4.0 model is sustainable background for organisation development. From this foundation, enterprises will build and operate smart factories, smart organisations, and smart products. The smart factories include intelligent quality control systems, real-time quality inspection, total inspection, and real-time evidence-based decision-making. Smart organisation towards lean organizational structures to adapt environment, smart allocation of resources needs, smart communication and collaboration between all stakeholders. Finally, Quality 4.0 gives a smart market prediction and customises individual products (smart products).

6 CONCLUSION

Using explicit inclusion and exclusion criteria, 53 papers were selected from the WoS database. The study has built a theoretical framework of TQM practices in Industry 4.0 based on socio-technical system theory from the literature review. The framework focuses on six dimensions of socio-technical perspective: Goals, People, Infrastructure, Technology, Culture, and Process/Procedures. TQM model adds advanced goals to gain customer satisfaction fulfilment. The authors introduce five main pillars of Quality 4.0, including technical factors, social factors, smart organisation, smart factory, and smart product.

This model needs to be extended to research for different fields such as production, services, education, agriculture, and etc. It also needs to be created constructs fulfilment of the model to open opportunities examining the model implementation in the future. The model can be the framework for academics to refer in further researches, as well as practitioner lead organizations to achieve success and a competitive edge.

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DETERMINANTS OF TECHNOLOGICAL AND NON-TECHNOLOGICAL INNOVATION FOR SMES PERFORMANCE IN THE ASIAN REGION

Michael Amponsah Odei, John Amoah, Abdul Bashiru Jibril, Jerry Asilenu

Abstract

Innovation can be seen as a complex trend, especially when it involves technical and non-technical aspects. In recent times, the Asian region has had a tremendous increase in innovation studies, but larger firms have received more attention. Larger firms have been factored in most analyses, despite the emergence of technological and non-technical innovation among small and medium scale enterprises (SMEs). This paper reviews some factors contributing to technological and non-technological innovation among SMEs across the Asian region. The main ideas on technological and non-technological dimensions of innovation studies were highlighted, followed by integrating various studies from different perspectives on the subject and discussing eventual research gaps and opportunities for further studies. The relationship between technological and non-technological innovation is complex. It thus needs several aspects such as the impact of technological and non-technological innovation among SMEs across the Asian region to understand fully.

Keywords: *innovation, firm performance, small and medium enterprises, technology, Asia*

1 INTRODUCTION

In recent times an extensive body of literature has surfaced on SMEs innovation (Crowley & Bourke, 2018). Innovation can be termed as the introduction of new ideas with simplified and smart technology (Ashford, 2000). Innovation is an overarching term that represents the organizational exploitation of digital technologies including information and communication technologies (ICT). Although many authors have carried out several reviews on the general literature of small and enterprise innovation performance across Asia (Geng et al. 2017; MacDonald & Turpin, 2008), there is ambiguity in SMEs' innovation across the Asian region.

SMEs are commonly defined as companies that have less than 250 employees (OECD, 2004). SMEs represent most business enterprises across Asia and contribute to employment and turnover across the region (Bala & Feng, 2019). Compared to SMEs in developed economies, SMEs in emerging economies have a greater impact on their countries' economies (Nizaeva & Coşkun, 2018). Small firms are the engine of growth and driving economic development across the Asian region (Zafar & Mustafa, 2017). They are believed to be more efficient in their operations because of job creation and expansion ability than larger firms. Thus, government in developing economies relies on SMEs as an instrument for national development (Amoah et al., 2021). However, less attention has been paid on SMEs and their role played in the nation's development.

Innovation provides SMEs with opportunities such as discovering of skilled and resource personnel, greater access to the market, financing opportunities, collaboration with academic universities for new inventions and more extensive product development (OECD, 2019. Innovation has ensured keen competition among SMEs and has strengthened the performance compared to larger firms (Loon & Chik, 2019). Moreover, the recent world bank report indicates that technological and non-technological innovation puts firms on the global market and thus rapid growth (Loon & Chik, 2019). Technological and Non-technological innovation

among SMEs has proven to be the solution for Asian countries development since they can put the Asian products across the globe. Again, the influx of technological and non-technological innovation can boost productivity and competitiveness (Fagerberg & Verspagen, 2009). Despite the potential benefits of SMEs' involvement in innovation, the reality is that several SMEs are reluctant to change or fail to benefit from new technologies.

Researchers on the theme of innovation across the Asian region seem to focus on the management of SME's operationality and its outcomes on an individual level (George & Prabhu, 2003; Rahman et al., 2010). Empirical evidence suggests larger firms perform better than SMEs in terms of innovation (Hall et al., 2009), and thus firms in developed economies benefit from innovation than firms in emerging economies (Crowley & Bourke, 2018). The outcomes associated with technological and non-technological innovation depends on several factors such as customer satisfaction, demands on the domestic and international market, competition, business environment (Pino et al., 2016). However, the manufacturing, retail and service firms in the Asian region are continuously experiencing downward growth in productivity, as shown in figure 1 below. The contribution of these sectors to the real GDP is consistently reducing over time as against the current global pandemic Covid-19. Hence, the main aim of this paper is to assess various factors contributing to technological and non-technological innovation performance across the Asian region. That is, this study seeks to review in-depth studies and conceptualize on technological and non-technological innovations and their impacts on firms involved in manufacturing, retail and service sectors across Asian region.

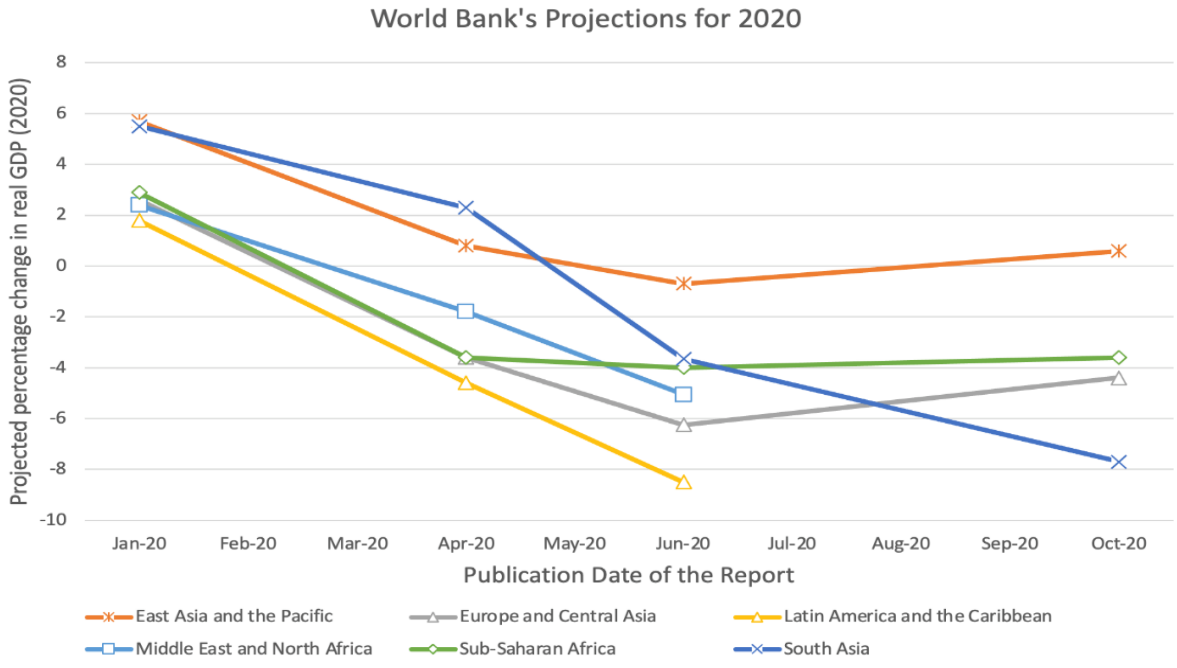

Fig. 1 – Global Economic Prospects. Source: World Bank (2020)

2 LITERATURE REVIEW

2.1 Concept of innovation

Innovation can be termed as the introduction of new ideas with simplified and smart technology (Schumpeter, 1939). That is innovation consist of both administrative and technical ideas. Administrative innovation comprises of new policies, procedures, and organizational reforms,

whiles technical innovation represents new products, technologies, and services. Van de Ven (1986) assert that technical and administrative innovations need to be combined since most of these innovations comprised of new technical and administrative components that help firms to operate successfully. According to Fagerberg (2004) further defined innovation as a combination of new ideas with existing knowledge using the firms' resources and implementing new practices. Innovation can be grouped into technological and non-technological innovation with keen interest in how it can radically have social and economic impacts. Technological innovation can be described as factoring product and process innovations through the combination of factors of production with inputs with the expectation of outputs. Non-technological innovation refers to all innovation activities that do not incorporate technological ideas.

2.2 Classification of Technological Innovation

The Organisation for Economic Co-operation and Development in 2004 classified technological innovations into product and process (OECD, 2004).

Product Innovation: This refers to the implementation of a new product or an upgrade of an existing product that may include integrated technical applications or other characteristics (Zhang et al., 2020). It integrates new ideas or a combination of both existing knowledge and method. Product innovation helps companies be technologically inclined, thereby enabling them to meet customers' demand and expectations based on their capabilities. Product innovation sprung up when firms with technical knowledge recognize and respond to customers necessities through product improvement. Kuncoro and Suriani (2018) study on small and medium enterprises profitability in Indonesia asserts that markets and technology are key components that result in the development of new product.

Process Innovation: This is the application of a new method of production or service delivery by firms. It involves significant changes introduced by the research and development department during production with competent skills, machinery, or software used during the innovation phase (da Silva, 2021). Usually, firms use it to reduce the cost of production or service delivery to deliver quality products or services. Process innovation is essentially introduced into a company's production or service delivery operations that transform the way in which products are manufactured at the industrial level. A study by Surya et al. (2021) affirmed that process innovations of small firms across the Asian region were motivated with the help of technical competencies from a pool of expertise through the sharing of new ideas resulted in technological improvement.

2.3 Classification of Non-technological innovation

This can be grouped into marketing and organizational (OECD, 2004).

Marketing innovation: This type of innovation refers to the implementation of new marketing strategies that have significant changes with product design, product placement, and product advertising to address customer needs and expectations to increase firm's sales (Sivam et al., 2019). The purpose is to identify new firms in the market and attract domestic and international market through different sales methods. However, according to Liu and Atuahene-Gima (2018) companies with a low level of research and development performance usually attribute their innovation activities to strategies that enable firms to compete through constant marketing through distributors (marketing innovation). Marketing innovation can be classified in three dimensions, namely: product strategy, promotion strategy and price strategy. These three effective strategies provide marketing measures in designing of products, distribution channels, sales promotion, and changes in sales strategies (Odei & Novak, 2020). The idea behind this is

to increase consumer's demand for products and help new entrants to the market. Theoretically, for companies to have a competitive advantage and increase consumer satisfaction, it is expected for such an organisation to harness its market technologies carefully. A study conducted by Bala and Feng (2019) emphasized that for firms to adapt to the changing trends on the market successfully, they need to rediscover their potential and exploit business opportunities using a competent workforce to develop new products and remain relevant in the competitive market. Also, market innovation leads to higher profit margin when it relates to learning from external relations such as new clients, and market competitors.

Organisational innovation: This refers to the implementation of a new method in companies' business practices, workplace organisation or how the firm relates to the external world (Simao & Franco, 2018). Organisational innovation is mostly intended to increase companies' performance by reducing expenses whiles improving workplace satisfaction. The terminology organisational innovation is often widely used to refer to organisational features of a particular product with various changes among organisational functions such as product development, marketing, environmental and public policies, health, and safety of employees. To support technological innovation in a company, organisational practices and certain changes need to be adopted.

Several studies have assessed the relationship between organisational and technological innovations by emphasizing the relevance of technological innovation as a major determinant driving organisational changes among firms in emerging economies across Asia, these studies have shown that technological innovation leads to organisational innovation, and companies are adopting technological innovations through the dedicated workforce, new production methods, sale and distributing channels in the markets (Nair et al., 2019; Hanadi & Aruna, 2013).

The various studies on technology and non-technological innovation have demonstrated that SMEs are not established accidentally, but they require effective management decisions, supervision, and efforts to maintain initiatives.

Small firms have the advantage of been innovative because they can make decisions without following bureaucratic processes and have a more flexible structure to adapt and implement change (Odei et al., 2020). On the other hand, large firms are more likely to be innovative because they have sufficient funds needed for expansion and facilities for training employees to apply their knowledge (Nair et al., 2019). Findings from other studies with quantitative studies have had a positive result rather than the negative relationship between size and innovation (Salehi et al., 2018; Damanpour, 1991). Regarding the relative effect of size on process and marketing innovations, authors posit that a firm's size correlates with technological and non-technological innovation (Hanadi & Aruna, 2013). Small companies tend to spend more resources on the process and marketing of their product because innovation can help firms to have a competitive advantage over competitors. However, larger firms develop process innovation faster and easier due to reduction in cost by given a certain percentage margin to the firm producing a large volume of output than companies whose output is small (Liu & Atuahene-Gima, 2018). Therefore, we propose that;

Proposition 1: Firm' size and funding are more likely to enhance process and marketing innovations.

Many researchers refer to a firm's investment in resource personnel as organisational capabilities (Ramaciotti et al., 2017). Organisational capabilities are essential for firms to deepen and broaden their knowledge by blending new ideas from research activities and disseminating knowledge across firms to boost technological and non-technological innovation (Lei et al., 2021). According to Odei and Anderson (2021), absorptive, adaptive, and innovative

capacity affect a company's ability to build and rebrand existing products to meet consumer's demand. The capacity of companies can well be enhanced through sharing of information, providing secured internet, stable power supply, hiring skilled and competent resource personnel to boost productivity (Ashford, 2000). This is because innovation requires integrating human capital, technological and non-technological capabilities to build a robust economy. Therefore, governments from emerging economies across Asia must ensure a smooth innovation policy, bringing competent employees together to share new ideas through academic research and implement innovation (George & Prabhu, 2003). We therefore propose that;

Proposition 2: Infrastructure and qualified resource personnel promote technological and non-technological innovations.

Digitalization and rapid internet diffusion have sprung up a new breed of criminals (Kshetri, 2010). These cyber-crime activities' have received massive attention in recent years: small and medium scale enterprises and governments from the Asian region are trying to tackle these security threat issues confronting the SMEs sector. A critical look into cybercrimes across the Asian region has indicated that cybercrime and strict privacy policy have prevented SMEs from expanding and adopting technological innovation. The records regarding crime patterns need new innovative strategies to help combat cybercrimes and make SMEs adapt to change and conducting their businesses more successfully. Internet hacking has compelled SMEs managers and operators to adopt secured software that allows them to trade successfully. Although governments across the Asian region are doing their best to curb the menace of cybercrime as little is known about the activities of the global cybercrime industry. Hence, the Association of Southeast Asian Nations (ASEAN) needs to adopt measures to tighten and strengthen security to prevent cybercrimes from supporting SMEs' sustenance. Few studies have accessed cybercrime in China, Indonesia, India and discovered that problems emerge in cloud computing, smartphone applications and other innovations in digital technology, which has hindered firms from shifting from the traditional method of operation to innovate (Broadhurst & Chang, 2013; Sarre et al., 2018). Therefore, we propose;

Proposition 3: Cybercrime and privacy policy likely to impact technological and non-technological innovations

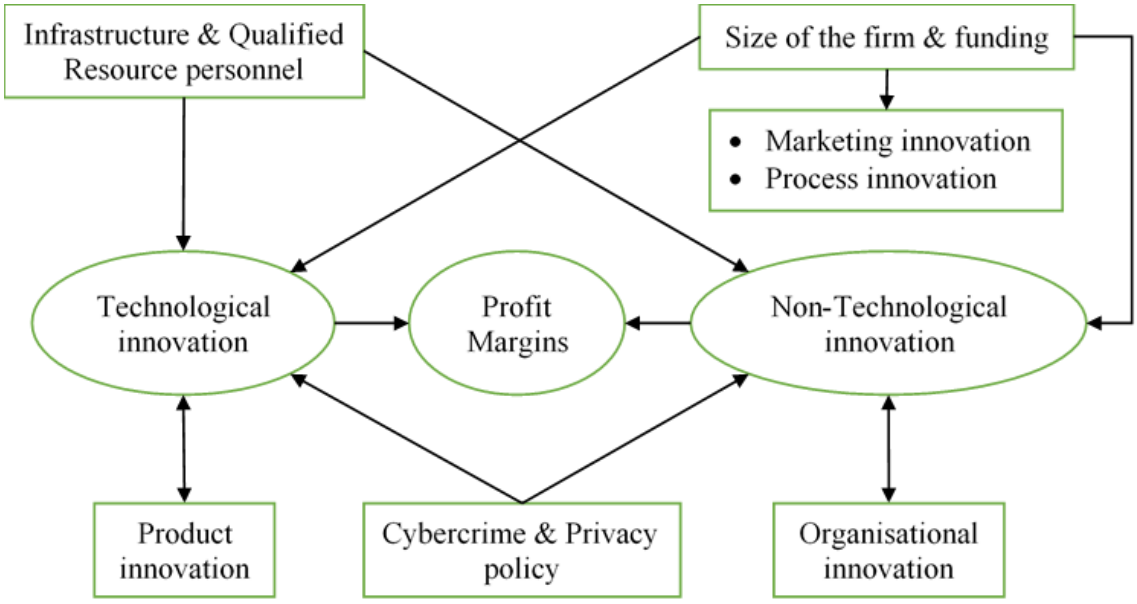

Fig. 2 – Conceptual model of the determinants of innovation outcomes in Asian Countries. Source: own research

3 METHODOLOGY

This study adopted the qualitative method as the primary approach for the research. The key technique used for this study was document analysis. Document analysis is defined as the use of printed and electronic materials to assess and evaluate documents to draw meaningful conclusions (Bowen, 2009). According to Bowen (2009), the use of document analysis provided enough information and content for this study which proved positive for this paper. Databases such as Scopus, Google Scholar and WoS were used to search for titles, keywords such as innovation across the Asian region and abstracts concerning innovation outcomes from 2000 to 2021. As a result of the objective in mind, forty papers were reviewed for the study out of the various papers downloaded from these databases. All articles downloaded were published in the English language.

Furthermore, other essential information was sought from secondary sources relating to the study topic as part of the method adopted for the study. Other authors and readers are encouraged to find interest in the published works of (Allen et al., 2017; Cassidy et al., 2018; Lins et al., 2021).

4 DISCUSSION & CONCLUSION

This paper has accessed the concept of technological and non-technological innovations among SMEs in the Asian region. The conceptual framework has shown a relationship among firm's size, non-technological innovation (marketing and organizational), technological innovation (process and product). Thus, SMEs operators are encouraged to intensify their innovation activities to create a competitive environment to boost innovation performance. Firms are encouraged to invest more into academic research that relates to the improvement of their production process, products, marketing activities, and hiring skilled and competent resource personnel to enhance productivity. SMEs that refuse to engage in innovation will find it difficult to compete with their rivals. Therefore, the Association of Southeast Asian Nations (ASEAN) federation can tax incentives for SMEs that engage in technological and non-technological innovation to help boost economic activities across the ASEAN region. Therefore, we conclude that technological and non-technological innovations among SMEs are essential for firms to grow and make huge profits.

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EXAMINING THE ROLE OF PUBLIC POLICY ON SMES INNOVATION ACROSS EUROPE

Michael Amponsah Odei, Petr Novák, Ahmed Rabiu Zangwio

Abstract

Public policies and regulations can either promote or hinder innovation activities within firms. Public policies and regulations can stimulate significant changes in new products and processes. However, public policies and regulation can create some obstacles and major restrictions, which poses a hindrance to small and medium enterprises (SMEs) innovation activities. Thus, while different types of policies have been practiced in an incremental and radical manner across Europe, there has been little empirical study and research propositions to investigate the effectiveness of public policies across Europe. In reviewing existing literature on public policy on SMEs innovation, it is highly probable to suggest research propositions regarding the significant role played by the European Union in promoting and sustaining SMEs innovation through mediating factors, namely, firm's willingness to adopt change, capacity to change and opportunity available for change. In addition, the current state of the SMEs sector in terms of theory and practice would offer varied options to propose how public policies can impact two different types of innovation, namely radical and incremental innovations. These study propositions would provide implications for both policymakers and managers of SMEs.

Keywords: *public policy, small and medium enterprises, innovation, Europe*

1 INTRODUCTION

The European Union (EU) continues to support and sustain small and medium scale enterprises (SMEs) innovation performance through funding and strict operational policies. Innovation continues to be a fundamental driver for the growth of national economies, and thus, support by governmental agencies provides an opportunity for technological innovation. Public policy has ensured sustainable development by establishing clear standards and allowing firms to operate while achieving their goals (Accordino, 2020). In addition, direct governmental support through the European Union funding for academic research and development, technical assistance initiative and tax subsidies for investment in innovative technology has created an enabling business environment for SMEs to flourish across Europe. These effective policies by the European Union have promoted and sustain SMEs innovation and thus the European region can boast of the emergence of new industries.

An example illustrating the impact of public policy on innovation is the European Union initiative in technology policy which aims at smart, sustainable, and inclusive growth with European policy. Concretely, the EU has set ambitious objectives on innovation in its ''flagship initiatives'' introduced in 2010 to address the digital agenda for Europe and the innovation union (European Union, 2011). Another example is the Entrepreneurship 2020 action plan which aims to enhance mass education and support SMEs managers in crucial phases of the business lifecycle (McCann & Ortega-Argilés, 2016). These initiatives were developed by the EU to create jobs and promote economic growth. The innovation union integrate innovational and technological research into production processes and provides a business model for firms. It combines excellent scientific research with the markets and helps develops a well-organised network within the EU. Therefore, to ensure collaboration throughout European firms, there is

a need for researchers to create an innovation-friendly environment that will benefit the economy and society at large (European Union, 2013).

While public policies and regulations help strengthen product and process technology among firms looking to innovate (Lopes et al., 2021), if not managed carefully, they can have a tremendous negative effect on innovation (Chen et al., 2021). Public policies and regulations can help innovation outcomes through unfair competition and bureaucracy (Karlson et al., 2021). Public policy can have a negative impact on a firm's productivity and ensure competitiveness due to the increased cost of operation. In recent years, industries across Europe have had a decline in competitiveness as a result of strict EU regulations compared to Asian countries and the United States (Patanakul & Pinto, 2014). These, EU regulations has caused policy makers in the EU to reduce the regulatory burden on SMEs (Aristovnik & Obadić, 2015). This means that public policy can have both positive and negative effect in SMEs decision making.

The main aim of this study is to examine the role of public policies in promoting and sustaining innovation performance. Based on the literature reviewed and the recent innovation strategy of the European Union, this paper presents a conceptual framework factoring the significant role played by innovation policies. Particularly, the paper will focus its attention on preposition such as SMEs contribution to innovation, specifically the willingness of the SMEs sector to adapt to change and the capacity to change when giving the opportunity. Again, we will place a major emphasis on a research proposition for investigating the impact of public policy on radical innovation versus incremental innovation across Europe. Therefore, the conceptual framework will significantly contribute to the existing literature as it provides helpful information for empirical research and offer implication for SMEs managers.

2 LITERATURE REVIEW

Schumpeter, in his review of the knowledge base economy, has had a significant impact on understanding firm's innovation performance as a dynamic force that causes institutional, social and economic growth (Schumpeter, 2003). As part of understanding the general role of governments in effective innovation policy making, it is very useful to know what innovation is, how innovation occur and what triggers successful innovations. Innovation can be termed as the introduction of new ideas with simplified and smart technology (Foray, 2014). According to Fagerberg (2004), further defined innovation as a combination of new ideas with existing knowledge using the firms' resources and implementing new practices. Innovation can be grouped into product, process and organizational with keen interest in how it can radically have social and economic impacts (distinguishing between radical, revolutionary, and incremental innovations. Again, innovation consist of both administrative and technical ideas. Administrative innovation comprises of new policies, procedures, and organizational reforms, whiles technical innovation represents new products, technologies, and services. Some authors assert that technical and administrative innovations need to be combined since most of these innovations comprised of new technical and administrative components that help firms to operate successfully (Fagerberg & Verspagen, 2009; Van de Ven, 1986). A study by Ashford (2002) on the influence of business regulations and policies on innovation is complex and depends on the type of innovation. The manner in which policies and regulations are drafted and executed should consist of the type of innovation (Jo et al., 2015). Firm's willing to change, capacity to change and the ability to change are key determinants for promoting technological innovation and thus governmental policies should be put in place to support these determinants. From the literatures reviewed on public policies, we propose a conceptual framework which

can represent relationship between the conditions set by the government through mediators such as willingness to change, the capacity to change and the opportunity to change.

Ashford's framework on innovational activities can be grouped into administration and technical innovations. He therefore proposes that certain conditions that promote innovations are: 1) enabling business environment 2) the basis for innovation to flourish and 3) a clear and specific target. We also suggest that the creation of enabling conditions requires series of public policy on innovation. Although the conceptual framework we are proposing includes information from old authors and previous public policies across Europe. In addition, various relationships contributing to SMEs innovation performance across the European region would be assessed. The following sections provides detailed discussion of the conceptual framework starting with creating a favourable business environment.

Proposition 1: The more public policy on innovation creates a favourable business environment for SMEs firms, the more it enhances firm's willingness to change, resulting in higher number of SMEs innovation.

As Ashford (2002) suggested, the willingness of SMEs firm to adopt change is among the prerequisite for technological change. The willingness of firms to have innovation hub is determined by the company's attitude toward change and sharing of new ideas. Ashford (2002) emphasized that firm's ability to change should be dependent on the behaviour of the firm because it will reward the organisation in diverse ways while the training given to employees provides the organisation with new ideas needed for technological advancement. As we assess the role of public policy on innovation, it can clearly be seen that governmental policies can create an enabling condition that can transform the organisation through innovation. To facilitate innovational activities, the European Union needs to create an environment free from cybercrimes and violent to attract new businesses and encourage old firms from not leaving the market (Lusthaus, 2018). One way to do so is to establish an innovation policy that minimizes crime and violent society (Kraemer-Mbula, et al., 2013). Governmental policies have supported businesses within the environment which has supported innovation and entrepreneurship through academic research. We, therefore, propose to conditions that those public policies incentives in the form of tax credit increases SMEs willingness to adopt innovation and an opportunity to change leading to higher number of innovation activities.

Proposition 2. Public policy provides incentives in the form of tax credit, the more it increases SMEs firm's willingness to adopt innovation, ability to change and opportunity available for firms to change, resulting in SMEs higher number of innovation activities.

A solid understanding of this proposition can be developed when SMEs identify those key elements in the tax systems which have a significant impact on firm's business owner's decision regarding the retention of earnings. To understand how the EU public policy affects SMEs management decisions, SMEs owners need to understand the effect of tax retention of earnings and the equity structure of SMEs. A study by Milner et al. (2020), in their findings, discovered that business owners in most EU countries recommended that effective public policy should provide incentives for retaining earnings and increasing own equity and thus the EU should reduce tax rates for SMEs to operate efficiently. Firms are willing to expand if governments provide flexible taxation systems to allow SMEs to operate freely. In the long run, this will provide stability for SMEs firms and will enable them to adopt innovative technologies to make them more efficient in delivering their core mandate to consumers. We, therefore, propose that more investment in academic research, the greater the perceived ability to change and thus higher number of innovations.

Preposition 3. The more SMEs invest in academic research, the greater the perceived ability to change and thus higher number of innovations.

Several kinds of research support this proposition. To promote academic research and lay foundation for innovation hub, the European Union has continuously funded research activities which can be evident in research grants for academic researchers across higher educational institutions. For instance, Internal Grant Agency among Czech Republic Universities has contributed to SMEs creation and provided incentives for academic researchers (Amponsah Odei et al., 2020). This grant has been sponsored by the Czech government and the European Union. Again, the Russel Group in the UK has collaborated with academic institutions and has led to the creation of ‘‘Spin-offs’’ activities in the UK. This has promoted existing companies with new ideas and contributed to the improvement in process and product development (Odei et al., 2017). The use of competent and skilled researchers provides the needed information and new ideas for process and product innovation. We, therefore, propose that public policy promotes the development of physical infrastructure, the higher the impact of public policy on SMEs perceived capacity to change, resulting in higher innovation outcomes.

Proposition 4. The more public policy promotes the development of physical infrastructure, the higher the impact of public policy on SMEs perceived capacity to change, resulting in higher innovation outcomes.

Most studies have revealed that innovative capabilities can be achieved through collaboration with external firms since such capabilities can contribute to an increase in new ideas or information about smart technology needed to be more efficient (Berchicci, 2011; Bauer, 2012). In addition to infrastructure, the European Union promotes innovation activities through ‘‘innovation hubs’’ (Odei et al., 2020). The innovation hubs serve SMEs as a platform for expert scientist and entrepreneurs to share knowledge about modern technologies such that they foster the capabilities of the firms. The European Union has launched a new start-up for SMEs with an attempt to promote entrepreneurship across Europe. This initiative by the EU has helped the transfer of research activities through collaboration with firms has increased the growth of new companies and helps firms to increase their capability. In addition to basic infrastructures, the European Union provide basic foundations through the promotion of academic research. Collaboration through academic research institutions has positively contributed to the growth of SMEs as they are able to commercialise their new ideas. Governments have actively encouraged innovation through research grants which have been used in setting up technology centres in most universities across the European region. For instance, Tomas Bata University in Zlín, with assistance from the Czech government through monetary funding, has established a technology transfer centre to boost entrepreneurship education in the Zlín region. Such funding from the government directly or indirectly has offered private organisations some competitive advantage once they achieve commercial capabilities. Such a policy should enhance firms' capability by increasing in knowledge and information that can be the basis for innovation.

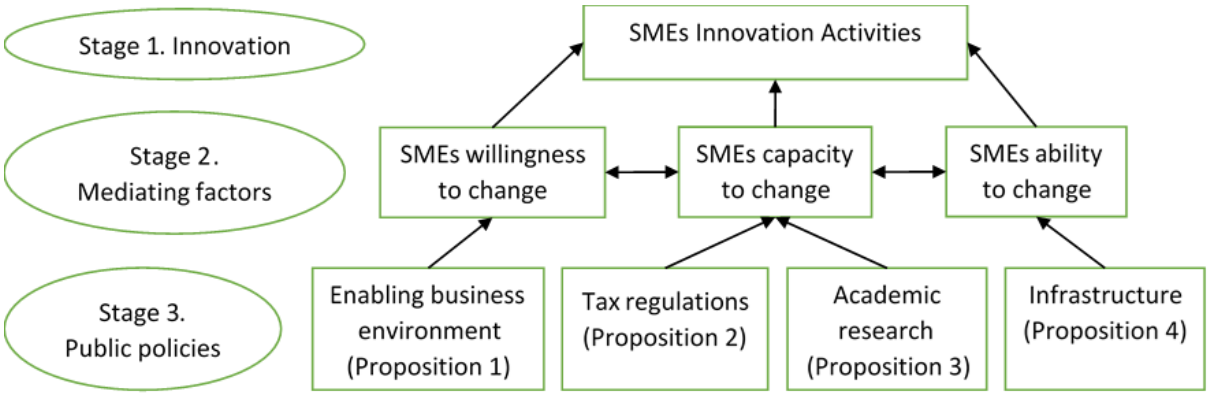

Fig. 1 – A framework for understanding public policy. Source: own research

3 METHODOLOGY

We searched for about 28 published studies (2000–2021) in 3 bibliographic databases (WoS, Scopus, Google Scholar) for qualitative studies that presented outcomes related to an innovation's adoption or implementation. Included studies had to assess latent constructs related to the "inner setting" of the organization, as defined using document analysis. Document analysis integrates constructs from relevant literature and addresses different domains, including inner organizational setting, characteristics of relevant literature work, outer setting; characteristics of management implementing interventions; and processes for implementation (Bowen, 2009). Document analysis is becoming a widely used framework in academic research and thus provided a useful framework for the current review. All downloaded articles were in English to meet the objective of the study. Other researchers are encouraged to read the work of (Edler et al., 2012; Van den Broek et al., 2018) when researching a qualitative study.

Other authors must investigate the impact of firm characteristics such as firm size, companies age, innovation process on the relationship between the characteristics of public policies and innovation. Additionally, future research can examine the impact of innovation on the mediating factors because SMEs ability to change may have a significant effect on the firm's willingness to change. Although public policies can contribute to organisational innovation practices, it would be more interesting to understand mediating variables and their effect to buttress further studies. We believe that other researchers should conduct a large sample study by collecting data from the European Union databases to assess the impact of public policy on SMEs innovation performance. Again, the impact of public policies on the different type of innovation, such as incremental and radical innovation, is worth investigating. The conceptual framework in this paper is straightforward and thus practical implementation may be challenging since this study is limited to the SMEs sector.

4 DISCUSSION & CONCLUSION

This paper contributes to the existing literature in diverse ways. First, in terms of the key determinants impacting SMEs innovation performance, several researchers have conducted investigations on innovation outcomes. Most of that research focused on organisational factors such as innovation process, organisational structure, team structure and support from employees within the firm. In this paper, we suggest possible alternatives on the role of public policy and propose four research propositions that should not be overlooked when assessing innovation across the European region.

Secondly, despite the fact that it has been recognize that public policy has significant impact on innovation, in this paper, we extend ideas by identifying such impacts through relevant mediating factors; namely SMEs willingness to change, capacity to change and firms having the opportunity to change. We argue that for public policy to promote and sustain innovation activities, there is a need to consider the mediating factors as well. This paper extends the original conceptual framework by Ashford (2002), which identified the role of public policy and its impact on the mediating factors.

Furthermore, as we present the relationship in the forms of propositions and conceptual framework for understanding the role of public policy on innovation, the listed propositions in this paper can later be developed into a research hypothesis to investigate the major drivers of innovation outcomes and the main role played by public policy across Europe.

4.1 Implication for researchers and managers

It is crucial to focus on the researching processes of firm's innovation as it motivated by public policies which require researchers to be conversant with different ways to measure each of the propositions mentioned in this paper. Furthermore, new ideas in theory and practice of public policy as well as innovation theory is very crucial for beginning a study. Considering the keen competition among SMEs to innovate; our paper offers varied managerial implications because they link public policies and relevant management decisions. Innovation policy in recent times has ensured competition and has driven organisational growth. Managers of SMEs should take advantage of public policy that promotes and sustain innovation across Europe. In order for firms to increase innovational activities within their jurisdiction and taking advantage of public policy, this paper can be used as a guideline. SMEs willingness to change, the capacity to change and ability to change should be factored not only at firm level but also at the individual level. Management should reward competent and skilled employees in order to have efficient performance. Innovation should be a shared responsibility and linked to the business strategy to ensure firms a competitive advantage over competitors across Europe (Odei, 2017).

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INTERREG V-A SLOVENSKÁ REPUBLIKA ČESKÁ REPUBLIKA SK-CZ 14-20

EURÓPSKA ÚNIA EURÓPSKY FOND REGIONÁLNEHO ROZVOJA SPOLOČNE BEZ HRANÍC

BIELE KARPATY

ŽILINSKÝ SAMOSPRÁVNY KRAJ

FOND MALÝCH PROJEKTOV

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OPTIMIZATION OF STOCK LEVEL BY SHOP FLOOR

Raphael Olakunle Olaniyi

Abstract

Efficient and flexible production planning through shop floor lot-sizing scheduling is critical for a manufacturing industry to remain competitive in the global market. Companies purchase and produce large stock before receiving customer orders in an attempt to control the time to the market and manufacturing costs. This research presents a critical and focused review of stock control with a particular emphasis on predicting the optimal level of stocks by the shop floor. Literature review approach was adopted in this research where secondary data obtained through archival research was used to support the arguments advanced in this report. It was shown that failure to calculate and maintain optimal stock level would lead to expensive overstocking, dead stock, stock spoilage, stockout among other inefficiencies. Moreover, structural and dynamic complexity of production systems have been a driving force in determining optimal stock levels so as to avoid inventory oscillations and the consequential cost implication. Healthy inventory levels ensure efficiency, profitability, improved productivity, and reduced cost. Digitization of optimal stock levels would be key to increasing profitability and flexibility. Inventory tracking and management systems can help in determining reorder points and carrying out inventory audits..

Keywords: *Optimal stock level, stockout, shop floor, manufacturing systems*

1 INTRODUCTION

This section introduces the concept of optimal stock level and highlights some of the factors that affect the optimal stock level. The effects of supply disruptions could be catastrophic like when there was shut down of European air space due to volcanic eruption in Iceland leading to dumping of 65 tons of vegetables and 3000 tons of roses and an estimated daily loss of about $2 million (Atan & Rousseau, 2016). This research thus seeks to address the following questions: What is the relevance of optimal stock level? What mathematical model would be applied in determining such an optimal stock level?

Mecalux (2021) defines optimal stock as the exact amount of inventory a company requires to satisfy regular demand without exhausting the inventory. Some of the factors that affect optimal stock level include customer demand, safety stock levels, product type, and lead time. A company failing to maintain optimal stock level could face expensive overstocking, dead stock, stock spoilage, losing track of inventory, and inefficient storage processes (Lopienski, 2021; Scholz-Reiter et al., 2006; Schwarz, 2018). Due to the structural and dynamic complexity of production systems, there ought to be appropriate inventory control policies to avoid inventory oscillations (Mecalux, 2021; Scholz-Reiter et al., 2006).

2 LITERATURE REVIEW

This section will explore stock management and a mathematical model for optimizing stock level. Adoption of technologies comes with benefits of improved inventory management, reduced labour and enhanced visibility but has a setback of cost implication and standardization issues (Bottani et al., 2009; Michael & McCathie, 2005). There is an enormous amount of data

that results from these technologies which can be converted to useful knowledge (Schniederjans et al., 2020).

2.1 The Need for Optimal Stock Level

Companies need to be able to coordinate supply chains effectively so that they can minimize costs, optimize shop floor, warehousing facilities as well as allocate customer demand to production (Daniel & Rajendran, 2005; Gebennini et al., 2009; Kittipanya-Ngam & Tan, 2020; Radhakrishnan et al., 2009). Minner (1997) observed that appropriate service level constraints need to be put in place to reduce occurrences of internal and external stockouts. Inventory optimization reduces lead times and costs, meets market demand and enhances customer service (Radhakrishnan et al., 2009).

2.2 Optimal Stock Level Determination

There are various approaches to production management which are considered to create an effective manufacturing environment, some of which include Materials Requirements Planning (MRP), Optimized Production Technology (OPT) and Just In Time (JIT). The JIT approach deals with producing the items at the desired quality and quantity at the precise time they are required. The MRP approach calculates the materials and components required to manufacture a product through three main steps; taking inventory of the components and materials available, identifying additional resources required and scheduling their production or purchase.

MRP improves efficiency, profitability and flexibility of the manufacturing operations by ensuring that the right stock is available in the production process exactly when it is needed and at the lowest possible cost. Use of MRP leads to reduced customer lead time, reduced inventory costs, inventory optimization, competitive product pricing, and improved labour productivity. However, MRP suffers from increased inventory costs, data integrity requirements and limited flexibility. The OPT approach is based on creating a near-optimum sequence of operations by identification and removal of bottlenecks and taking into account priorities and capacities.

Moreover, Kanban Order Quantity (KOQ) and Economic Order Quantity (EOQ) are considered when setting the standard replenishment quantities. Kanban is basically a lean just-in-time (JIT) approach and follows either empty-a-bin or break-a-bin method. KOQ takes into account the actual demand making it flexible but ignores ordering and holding costs resulting in a higher number of orders (Lyles, 2018). EOQ helps identify the optimal number of units to be bought while reducing the total cost as much as possible.

According to Khalil et al. (2021), inventory management answers the questions of when to order and how much to order so as to optimize the total inventory. It should be noted that the inventory level is dependent on time with a continuous flow determined by replenishment as shown in figure 2.1. Figure 2.2 shows a generalized system where demand is constant and known. With such a deterministic demand, an economic order quantity (EOQ) model which considers the trade-off between ordering cost and storage cost is used for replenishing inventory as shown below (Kontus, 2014).

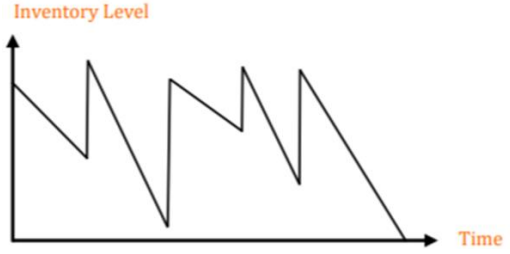

Fig. 1 – Inventory fluctuations based on time. Source: Khalil et al. (2021)

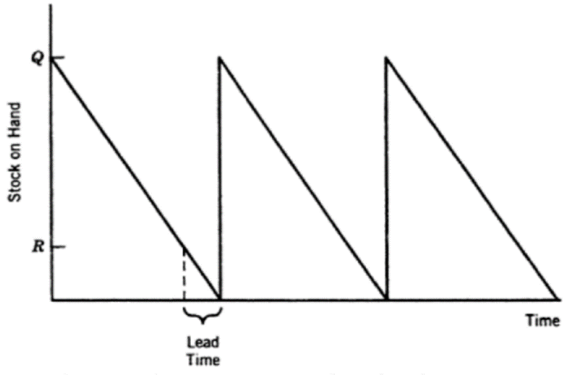

Fig. 2 – Deterministic demand with optimal reorder point, R, and order quantity, Q. Source: Sherbrooke (2006)

This is the optimal stock level formula we discuss further as shown in the equation (1) below and is based on the Wilson model (Greeff & Ghoshal, 2004; Mecalux, 2021).

$$\text{Optimal stock level} = [\text{optimal order quantity}] + [\text{minimum stock level}] + [\text{safety stock level}] \quad (1)$$

The optimal order quantity is given by

$$Q = \sqrt{\frac{2 \times K \times D}{G}} \quad (2)$$

Where Q - optimal order quantity, D - annual demand for raw material, K - cost of each order, and G - cost of storing a product at a given time.

The minimum stock level is given by

$$\text{Minimum stock level} = [\text{Quantity consumed per unit of time}] * [\text{Supplier lead time}] \quad (3)$$

The safety stock level is determined as below

$$\text{Safety stock} = (\text{MPLT} - \text{SLT}) * \text{APD} \quad (4)$$

Where MPLT - maximum procurement lead time when an incident occurs, SLT - supplier lead time under normal circumstances, and APD - average product demand.

2.3 Inventory Control

Inventory control deals with satisfying the incoming demand while minimizing the average cost per time period to avoid inefficient production lines and supply lines as well as dissatisfied customers (Ekren & Mullaoglu, 2020; Katana, 2020; Scholz-Reiter et al., 2006; Schwarz, 2018). An inventory management system should ideally help in addressing review period, the reorder level and restock quantity of each product (ClarusWMS, 2020; Ekren & Mullaoglu, 2020; Schwarz, 2018; Zhang, 2018).

The three main elements for shop floor control are scheduling, dispatching and monitoring (Bauer et al., 1994). Scheduling requires establishing a plan based on timely knowledge and data that ensures that all production requirements are fulfilled within a specified time frame. Dispatching involves implementing the plan while paying regard to the current status of the production system. Monitoring entails keeping an eye on the status of the vital components within the production system during the dispatching process which can be done manually or through automation.

The concerned team should have a feasible output of finished goods and the manufacturing lead time so that the raw materials inventory is managed appropriately and avoid taking up valuable storage space and drive up the carrying costs (Rubio & Wein, 1996; Schwarz, 2018; Zhang, 2018). Future orders can be anticipated by looking into historical sales, competition sales and seasonal sales emerging from holidays which can help in aligning production based on forward scheduling (earliest time a customer's order can be completed) or backward scheduling (determining production start date informed by available resources from the due date) (McPhetrige, 2016; Schwarz, 2018).

It is an undeniable fact that putting systems and policies in place would lead to better decision making on inventory, employee status and production progress as well as reduce wastage, maximize output and reduce downtime (Katana, 2020). These control systems require data collated from warehouses, purchases, orders, shipping, customer satisfaction and loss prevention (Chen et al., 2003; Schwarz, 2018; Su & Shiue, 2003). Schwarz (2018) noted that about 62% of customers had stopped doing business with a brand citing poor customer service with the main complaints being frustration over out-of-stock and backordered items.

Companies mainly use periodic or perpetual tracking systems for their inventory control system (Schwarz, 2018). A periodic inventory system relies on regular or occasional physical counts of inventory whereas a perpetual inventory system continually updates the inventory numbers ensuring an accurate stock on-hand accounting at all times.

3 METHODOLOGY

This researcher adopted a literature review approach. This enabled the researcher to have an in-depth understanding on optimal stock level and how to predict it by shop floor. Secondary data obtained through archival research was used to support the arguments advanced in this report. The data used is mainly qualitative. The researcher identified multiple reputable resources and articles that were reviewed to help summarize how to predict the optimal level of stocks by shop floor. The envisioned problems were that the secondary data could have been biased or unethically collected and this was mitigated through reviewing more resources from multiple sources and sectors to achieve diversity.

4 RESULTS

This research aimed to determine the relevance of optimal stock level and investigate a mathematical model that would be applied when determining the optimal stock level. The literature review has shown that determining and maintaining an optimal stock level minimizes storage costs and maximizes profitability. A failure to do so would lead to stockout, dead stock, stock spoilage and inefficient storage processes. Although there are various approaches that can be adopted when determining replenishment levels such as JIT, OPT, MRP and KOQ, the literature review has shown that EOQ would be the best approach. The mathematical model in line with this approach that would be used when determining the optimal stock level is as shown below:

optimal stock level = [optimal order quantity] + [minimum stock level] + [safety stock level]

5 DISCUSSION

Companies are seeking to save time, high storage costs, keep the shop floor organized and avoid stockouts to satisfy customers. Maintaining optimal inventory levels can be achieved through implementing an inventory tracking and management system, determining reorder points, and

carrying out inventory audits. Where companies use perpetual and periodic tracking systems, it is advisable to integrate the systems since a perpetual system also suffers from stolen goods, broken items, loss, errors and improperly scanned items which can be corrected by having manual stock taking process.

Digitization of optimal stock levels would increase efficiency, profitability and flexibility. The adoption of technology cannot be overlooked as it would lead to intelligent systems that make real-time decisions robust to various production requirements. Literature has shown that various approaches can be used by companies to help them maintain optimal stock level but EOQ stands as a reliable approach when determining the replenishment levels. The researcher would recommend further investigating the applicability of this approach when dealing with perishable products.

6 CONCLUSION

Through review of existing literature, a formula for determining optimal stock levels was showcased. It would be hard to achieve a perfect production system hence the need to incorporate reliability in an inventory system. The researcher notes that the EOQ approach is very well applicable where the rate of demand is constant, and the purchase or production cost is fixed. There is a possibility that the approach would be costly when dealing with perishable goods or where a company's carrying cost is underestimated.

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DOES TERTIARY EDUCATION LEAD TO ECONOMIC GROWTH OF EU MEMBER STATES?

Olesya Petrenko, Jan Čadil

Abstract

Rising interest in the role of tertiary institutions in regional economic growth is creating space for multi-disciplinary discussions and research in education, economics of education and human resources management. It is crucial to determine what impact universities have on economic growth as producers of human capital and innovation implementors in their regions. A new definition of effective universities is currently being established. Yet research reports on human resource management in education, specifically, tertiary education, are limited in number, disintegrate and incongruent. It was attempted to identify and explore the theme and existing research gaps through extensive literature review and setting up econometric models. The goal is to offer a direction for future research, define and decompose the effect of tertiary education on growth. It is indicated there is a lot to add to the state of the art, as well as to the practical reliable data research. It was found that while tertiary education does not lead to GDP growth directly, however, there is an effect of scientific and technical tertiary education.

Keywords: *human capital, economic growth, GDP, tertiary education*

1 INTRODUCTION

The purpose of this research is to define and measure effects of tertiary education on economic growth of developing and advanced economies in EU countries using the regression analysis in order to determine further research questions and outline the research strategy. It is evident that universities:

1) build up institutions and purchase goods and services from the region (Belenzon & Schankerman, 2013)

2) stimulate innovations in their regions (Toivanen & Väänänen, 2014)

3) produce quality human capital (Gennaioli et al., 2013)

In the current paper, a developing and developed EU countries classification is based on the IMF's Country Classification System with 22 countries belonging to advanced economies group and 5 countries (Bulgaria, Croatia, Hungary, Poland, Romania) to emerging and developing economies group. Economic growth is measured by % GDP per capita.

The following research hypothesis was formed:

H0: EU Countries that invest more into tertiary education do not have a higher economic growth rate compared to other countries.

In this paper it is attempted to consolidate the results of research work in previous studies in tertiary education management, define the trends and topics that have been covered in order to recognize the state of the art and possible research gaps. A broader scope incorporates HRM practices in making tertiary education units more efficient, as it includes a number of articles on how to measure efficiency empirically. It is believed that such a comprehensive approach will give more specific insights on current HRM strategies used to develop regional higher education and economies in Europe.

2 THEORETICAL BACKGROUND

The relationship between the level of education of workforce within a country and effective functioning within organisations providing tertiary education is crucial to understand in order to build up a system that can deliver quality workforce to the market (Faggian & McCann, 2009). In some papers (e.g. Agasisti et al. 2020) it is believed that effective universities would either employ fewer people to achieve the same results, or keep the number of employees increasing their results. Such universities may ignite more interest and incentives to attract younger generation to take part in their study programmes as well as establish strong bonds and collaborations among businesses in the region.

A number of researchers have been working hard to describe strategies of how universities normally engage in social and economic development of the region. In 1996 Etzkowitz described a triple helix model, other researchers widely use econometric approaches that are based either on macroeconomic or regional development models.

Over the last few decades it is becoming increasingly important to calculate and recognise the economic impact of universities and other organisations providing tertiary education. Huggins and Johnston (2009) described universities as drivers of regional innovation system. It is crucial, however, to look at the human capital and ways it is managed (recruited, trained, sustained) in order to determine possibilities of sustainable growth in results in higher education.

It is crucial to define what efficiency in education is because researchers and educators worldwide often feel concerned about techniques how to pursue so-called efficiency. These concerns mainly stem from the idea that if educators and university staff in general starts focusing more on being efficient, the very concept of higher education might suffer as more attention is given to meeting certain requirements. The term "efficiency" is typically explained as the opportunity to provide the best educational product for a given budget. It can work in two main directions: same resources-better results or fewer resources-same results.

According to the traditional approach, the factors that have an effect on the educational process are input factors, and the results that appear after the education process is finished are called the outputs. In a nutshell, traditional approach is not aimed to define the "production process", which essentially implies that inputs (e.g. number of administrative/teaching staff, educational environment, availability of certain equipment, etc.) are gradually transformed into outputs (e.g. economic growth of the region, number of graduates, etc.). The studies that were carried out in the last few decades, mainly in the new millennium, infer that there is an option to improve efficiency without necessarily making the quality of the education and the higher education system worse off. According to Agasisti et al. (2020), universities may be viewed by general society as social and educational venues that help individuals acquire specific skills to be able to meet economic needs and fit the current market demand perfectly well. It was demonstrated by Shattock (2010) that imposing strategical thinking (align priorities, values and incentives of the university to the ones defined by local/regional/national authorities) for university management is one of the key elements to enhance university's performance and efficiency. Understanding the role of human resources management in tertiary educational venues helps to sift through a number of management mechanisms in order to select the ones that lead to efficiency and consequently, economic growth.

It is necessary to point out there is not universal meaning of the term "university efficiency". Researchers focus on various aspects of how to measure the efficiency and what methods to use. It might happen due to the fact there are a number of higher education systems in the world, culture, society, policies, history and many other factors have an impact on the development of

not only the higher education venues but also HRM practices that vary from university to university. Although researchers and officials are becoming increasingly interested in performance measurement in higher education (Ruben, 1999; Broadbent, 2007), very few models of performance measurement were transferred from the for-profit sector and later adjusted to suit such public organizations. Typical approaches to human performance evaluation include audit, qualitative and quantitative methods, balanced scorecard (BSC) method, etc. However, chances are, they might not be able to deal with approaches that measure sophisticated higher education services and education outcomes.

The concluding issue that might have a strong connection with efficiency of tertiary education organizations is policy, both internal and external regulations for managing a higher educational company. Researchers Capano and Regini (2014) claimed that European universities confronted national reforms that affected teaching and research policies. Therefore, it is useful to analyse literature that describes decision-making processes at universities.

Societies and governments generally expect universities to fit in current stages of economic development, play a major part in regional development, bond with prominent for-profit and non-profit organizations, although the budget on tertiary education has been decreasing in many EU countries. That means the universities may need to seek out the ways to receive funding from joint projects and programmes as well as focus their attention on research grants and scientific progress.

The universities in most EU countries have been attempting to transform according to some commonly accepted rules and policies (Gornitzka et al., 2005, Lazzaretti & Tavoletti, 2006; Maassen & Olsen, 2007; Trakman, 2008). These policies should include quality check of both teaching and research and well-established funding mechanisms that should be competitive. It was attempted to reform governance by making higher education institutions more autonomous by giving greater power to the managers, thus the decision-making process could become more independent from committee checks and voting.

In particular, researchers Capano and Regini (2014) implied that little attention was given to internal changes within organization, whereas policy makers and analysts mainly focused on implementing external policies. However, it is obvious that universities obtain different resources, face different obstacles from time to time and are managed by people who perceive and implement policies differently based on their "power resources, culture and learning abilities." Therefore, the role of people managing higher education institutions as well as their cultural background, current obstacles, interests and limitations should not be underestimated.

3 METHODOLOGY

It is a priority to make an accurate review for the current research in order to relate it to the existing knowledge and make it credible. This study involves repeated observations of the same variables over a period of time 2004-2019 in 27 EU Member States. The paper might include one or more of the following procedures: generalization, analysis and interpretation. GDP per capita and Fixed Capital Formation, economic growth, and physical capital investment, respectively, were attained through the Worldbank Database. Tertiary education information on student enrolments, gender differences and study programmes were taken from Eurostat.

In the scope of the research it is necessary to:

1) consider current approaches to analysis of human capital, its assessment and methodology of its use as a part of endogenous growth models;

2) modify a few existing economic growth models by incorporating the impact of tertiary education in the long-term economic growth, and determine terms of the growth rates of the main macroeconomic indicators;

3) build panel data tables for empirical evaluation of the production function of the selected and modified models;

4) carry out analytical calculations on the proposed models using data from developed and emerging/developing economies and draw conclusions.

The model will be tested in calculations with statistical information taken from the Worldbank Database, October 2020 on EU Member States. In order to address the hypothesis, it is necessary to create panel data on EU Member States according to their tertiary investments, (%GDP per capita in PPP, international dollars) and other regressors.

As a result, the following calculations may be necessary to make: for each country, a series of specific cumulative human capital. The highest level of specific accumulated human capital might be particularly important.

The empirical framework is based on the following baseline model (1):

$$\Delta \log Yit = \beta_0 + \beta_1 \Delta \log X_1 + \beta_2 \Delta \log X_2 + \ldots + \beta_{22} \Delta \log X_{22} + \varepsilon \quad (1)$$

where Yit is the GDP per capita in PPP in country i and at time t; ε is the impact of other factors that were not included into the model and X represents the matrix of regressors (Table 1) for randomized characteristics, which have been included in the model on the basis of evidence in the literature. In order to check the model for consistency and lack of autocorrelation, Breusch-Godfrey/Wooldridge test was performed to test against autocorrelation. The test verifies the assumption of serial independence in the original errors, which only holds if the differenced residuals do not show significant autocorrelation.

Tab. 1 – The Matrix of Regressors. Source: own research, WorldBank, Eurostat, Czech Statistical Agency

Population growth (annual %growth)	x2
LOG - Energy use (kg of oil equivalent per capita)	x4
Trade (% of GDP)	x5
Urban population (% of total population)	x6
Government expenditure per student, tertiary (% of GDP per capita)	x7
Start-up procedures to register a business (number from 1 to 10)	x8
New business density (new registrations per 1,000 people ages 15-64)	x9
Educational attainment, at least Master's or equivalent, population 25+, total (%) (cumulative)	x11
Government expenditure on education, total (% of GDP)	x12
Labour force with advanced education (% of total working-age population with advanced education)	x13
Labour force with advanced education, male (% of male working-age population with advanced education)	x14
Gini index (World Bank estimate)	x16
Share of graduated students majoring in technology/sciences in total population	x18
Total graduated students share, % of total population aged 15-64	x20
Number of universities per 1000 total population (how many people belong to 1 university)	x22
LOG - GDP per capita, current prices PPP US dollars	y1

4 RESULTS

H0: EU Countries that invest more into tertiary education do not tend to have higher economic growth rate compared to other countries.

It can be suggested that looking into the policy on tertiary education in Finland, Denmark and Sweden is important as it might help to understand the impact of tertiary education on economic growth which is expected to be determined in the framework of the current research.

The result of the regression analysis showed there is a statistically significant model which has a large share of explained variance R^2=0.85 (probability that F criteria will be less than its critical value). Durbin-Watson coefficient is also significant for this model (1.78), which suggests there is no autocorrelation and the model could be considered reliable. Wooldridge test for fixed effects in panel data does not reject the null hypothesis that there is no autocorrelation. The model was checked for normality of residual values, their multicollinearity and heteroscedasticity. In order to ensure that the current model is specified properly and works correctly, Variance Inflation Factor (VIF) was calculated. It measures the extent by which the variance of Y1 is influenced by correlations with the selected regressors. For this model all VIF values are below 10, that fact does not indicate multicollinearity.

Tab. 2 – Model 1: Fixed-effects, using 162 observations, included 27 cross-sectional units. Time-series length = 6. Dependent variable: y1. Source: own research

	Coefficient	*Std. Error*	*t-ratio*	*p-value*
const	−119481	32793.2	−3.643	0.0004
x2	13080.4	1619.96	8.075	<0.0001
logx4	13305.5	7444.45	1.787	0.0764
x5	112.563	16.6785	6.749	<0.0001
x6	341.591	102.585	3.330	0.0012
x7_1_1	143.323	161.325	0.8884	0.3761
x9	−227.419	220.925	−1.029	0.3054
x11_1_1	−0.00341719	0.00523372	−0.6529	0.5151
x12_1_1	−882.163	1109.52	−0.7951	0.4281
x13	2246.23	518.942	4.328	<0.0001
x14	−1700.73	414.186	−4.106	<0.0001
x16	752.810	254.678	2.956	0.0038
x18	4.53647e+06	1.35165e+06	3.356	0.0011
x20	29.3008	187.350	0.1564	0.8760
x22	2.61088	8.83302	0.2956	0.7681

Tab. 3 – Model 1: Fixed-effects, using 162 observations, included 27 cross-sectional units. Source: own research

Mean dependent var	41124.29	S.D. dependent var	18407.14
Sum squared resid	7.49e+09	S.E. of regression	7162.294
R-squared	0.862704	Adjusted R-squared	0.848598
F(15, 26)	245.8363	P-value(F)	4.32e-24
Log-likelihood	−1659.452	Akaike criterion	3350.903
Schwarz criterion	3400.305	Hannan-Quinn	3370.961
rho	−0.074579	Durbin-Watson	1.783103

Tab. 4 – Model 1: Fixed-effects, using 162 observations, included 27 cross-sectional units. Test results. Source: own research

Wooldridge test for autocorrelation in panel data
Null hypothesis: No first-order autocorrelation (rho = 0)
Test statistic: t(26) = -0.535397
with p-value = P(|t| > 0.535397) = 0.596926

Test for normality of residual
Null hypothesis: error is normally distributed
Test statistic: Chi-square(2) = 5.98506
with p-value = 0.0501603

Distribution free Wald test for heteroskedasticity
Null hypothesis: the units have a common error variance
Asymptotic test statistic: Chi-square(27) = 307.67
with p-value = 2.14711e-049

White's test for heteroskedasticity
Null hypothesis: heteroskedasticity not present
Test statistic: LM = 158.147
with p-value = P(Chi-square(135) > 158.147) = 0.0845005

Hausman test statistic
H = 25.5168 with p-value = prob (chi-square (15) > 25.5168) = 0.043419

(A low p-value counts against the null hypothesis that the random effects model is consistent, in favour of the fixed effects model).

Due to the fact that panel data was used in the study, Hausman test was performed in order to differentiate between a fixed effects model or a random effects model. The null hypothesis that the random effects model is consistent is rejected with a low p-value 0.043. This means fixed effects model appeared to be more preferable. It was intended to test the model with the White's test on heteroskedasticity. The test statistic TR^2 = 158.147 returned the p-value = P (Chi-square (135) > 158.147205) = 0.0845. This p-value is not inferior to 0.05, the null hypothesis of not having heteroskedasticity is not rejected and it is concluded that the error variance is constant for all values in the sample, the errors are homoscedastic. The test statistic for normality returned a Chi-square value of 5.985 with a p-value 0.0501 therefore, the residuals are normally distributed.

The hypothesis Ho is therefore, rejected. It can be concluded that the EU Countries that invest more into tertiary education, tend to have a higher rate of economic growth (Finland, Denmark and Sweden) that is determined by the share of total graduated students in relation to the population aged 15-64, share of graduated students majoring in technology/sciences, Government expenditure on education (% of GDP), % of total with at least Master's or equivalent education. Therefore, higher education, especially education in technology and sciences plays a crucial role in the economic growth of all EU Member states. EU Countries that invest more into tertiary education, tend to have higher economic growth rate compared to other countries. It could be pointed out that tertiary education in developed countries may be viewed in the context of the structure and development of a particular economy. It might be important to decompose the tertiary education into smaller components (e.g. taking separately ISCED levels 5, 6, 7 and 8) and see the impact on the economy separately.

It may seem that women deliberately opt out of studying in programs related to science and technology (Eurostat data, 2013-2018). In that case, it might be helpful to divide the impact of tertiary education in science and technology on economic growth between men and women to see whether men have a higher impact because of the education structure.

5 DISCUSSION

The author acknowledges space for theoretical contribution by attempting to identify factors in tertiary education that have an effect on general well-being of a country. These factors are critical to understand in order to develop a successful education system.

A possible limitation would be that a great number of existing research papers with the help of neoclassical models provide little confidence that they do measure the growth accurately. There is little impact of these results on real policy-making. A way to overcome these limitations could be to investigate and later choose multiple models that shade light on various ways of how to determine growth. Alternatively, other determinants of economic growth apart from

GDP could be tested in the models. The strategy of narrowing down possible options and contradictory evaluation (that typically happens because of cultural influences, social and economic institutions, different approaches of data collection) would allow to opt for statistically significant outcomes that could be explained with the help of econometric analysis.

The share of women with tertiary education in many EU member states is today higher in comparison to men. However, their participation in scientific and technical study programs remains low. In future we intend to prove that it is especially the share of students enrolled in science and technology programs that has the positive effect on economic growth.

6 CONCLUSION

Despite the limitations mentioned above, we were able to spot a growing interest in the connection between tertiary education organizations and the economic growth. Firstly, it can be concluded that the EU Countries that invest more into tertiary education, tend to have a higher rate of economic growth (Finland, Denmark and Sweden) that is determined by the share of total graduated students in relation to the population aged 15-64, share of graduated students majoring in technology/sciences, % of total population with at least Master's or equivalent education. Therefore, higher education in technology and sciences plays a crucial role in the economic growth of all EU Member states. EU Countries that invest more into tertiary education, tend to have higher economic growth rate compared to other countries.

It may seem that women deliberately opt out of studying in programs related to science and technology. In that case, in future research it might be helpful to divide the education impact on economic growth between men and women to see whether men have a higher impact because of the education structure.

It is crucial to determine what impact universities have on economic growth as producers of human capital and innovation implementors in their regions. A new definition of effective universities is currently being established. To build such a transparent system that could allow us to determine the efficiency of a higher education organization would greatly need clear explanation for managers and policy makers so that synergy between policy, management, human resources, professionals and students could be reached and the system overall could work more effectively providing the world with better opportunities.

The advantages the paper brings to the scholars are as follows: by investigating and consolidating the literature published over the last two decades it gives scholars a clear insight on what Human Resources Management in Higher Education is and what sources are of a specific value; by identifying the gaps in theory and methodology it can offer new implications and suggest possible research directions.

It is suggested that in future the scholars may develop and expand the subject themes, for example, study gender differences within an HE institution in science and technology and determine if there is any relation to efficiency and organisation’s connections to the industries.

Moreover, studies show that the system needs to be transparent so that the efficiency of the tertiary education organization could be determined. Therefore, we encourage scholars to develop and extend theoretical and methodological research base as well as test these theories and methods empirically. To build such a transparent system that could allow us to determine the efficiency of a higher education organization would greatly need clear explanation for managers and policy makers so that synergy between policy, management, human resources, professionals and students could be reached and the system overall could work more effectively providing the world with better opportunities.

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VIRTUAL TRAFFIC LIGHTS – SYSTEMATIC MAPPING STUDY

Mihael Radovan, Boris Tomaš

Abstract

10 years ago, Virtual Traffic Lights was new paradigm in the inter-vehicular communication, IoT and smart cities field, considering the idea of improved traffic control in the urban areas with traffic congestion, without any need for road infrastructure. The system is based on Vehicle-To-Vehicle (V2V) communication using Dedicated Short-Range Communication (DSRC). The aim of this paper is systematic mapping and classification of relevant papers published in journals which are covered by most important scientific citation databases – Scopus and Web of Science. All papers will be classified into categories depending on publication type, applied methods and paper maturity. It will be analysed which papers are most cited, which authors wrote most papers, and in which period of time is published majority of papers.

Keywords: *VTL, VANET, V2V, IoV, IVC*

1 INTRODUCTION

In last decade, technological development in all fields of industry is focused to become smart, or smarter, and fast or faster. The transportation is very important field in human reality, and intention is to produce smart, connected cars, and in very close future autonomous self-driving cars. To accomplish this very demanding task, it is necessary to invent one or more communication protocols, enough robust to keep communication between moving objects in various situations, especially in urban areas with plenty of buildings that produce interference and noise.

Inter-vehicular communication (IVC), based on ad-hoc networks – VANET (Vehicular Ad-Hoc Network), was introduced in 2001 as vehicle-to-vehicle communication to provide road safety and some other services (Toh, 2001). A synonym for IVC is Vehicle-To-Vehicle (V2V) communication, which is subset Vehicle-To-Environment (V2E) or Vehicle-To-Everything (V2X), all together called Internet of Vehicles (IoV). VANET can use any type of wireless technology: WLAN (Wireless Local Area Network), LTE (Long Term Evolution broadband communication for mobile devices), VLC (Technology for infrared communication), DSRC (Dedicated Short Range Communication.

Research in this field started in 2000 in university labs, and continued in automotive companies such General Motors, Ford, Toyota, Honda, Volvo, Volkswagen, Daimler and many others, as well as Car-2-Car Communication Consortium.

Virtual Traffic Lights (VTL) was first mentioned and introduced in 2010 by Ferreira and others, as a proposal for migration of traffic lights to in-vehicle virtual signs supported only by vehicle-to-vehicle communications, based on DSRC communication protocol (Ferreira et al., 2010). Until now, this topic main scope of more than 50 papers, regarding citation databases Scopus and Web of Science.

Section 2 covers theoretical background and describe base idea of this technology, proposed in the initial paper. Section 3 describes methodology used to map researches based on this topic, and Section 4 shows results of this mapping. Section 5 discuss current status as well as need for changes or improvement. Finally, Section 6 gives conclusions and proposals for future research.

2 THEORETICAL BACKGROUND

Regarding the initial paper (Ferreira et al., 2010), in the USA is just 0.5% of all road intersections covered with traffic lights; this refers to the whole country – in large cities it is about 25%. Similar situation is in some European cities, e.g. Dublin, capital city of Ireland or Porto, second large city in Portugal (Fig.1). Also, more than 70% of all traffic lights are configured to work under fixed intervals, so they are not adoptable to dynamic condition on the road. Some of this units are configured to work just as part-time, in some fixed parts of day, when traffic is heavy, otherwise they are off.

Fig. 1 – Map of Porto. Red dots (328/2000) are traffic lights on road intersections. Source: (Ferreira et al., 2010)

There were made many scientific researches in last 50 years, and developed many complex algorithms to optimize work of traffic lights on the road intersections, but they are all based on the roadside infrastructure with sensors and interconnection. To make these all units adoptable to dynamic road conditions, it would be necessary to make hardware upgrade on each traffic light, which is pretty expensive and time demanding.

VTL proposes completely new paradigm, based on in-vehicle system with DSRC communication, GPS and digital road map. The basic idea is that vehicles closest to the intersection from opposite or vertical direction exchange information about its position in order to decide who will get the priority. One of them, who is closest to the centre of intersection, become "leader" and work as a traffic light, staying at the intersection starts the new cycle and sends red light to its lane and opposite side of the intersection, and green light to the vertical side(s). During this time period, other vehicles transmit the status of intersection to drivers over built-in display in the car. After defined time of cycle is over (e.g. 15 seconds), or if the green side of the road is empty, the red phase is ended. Leader changes message from red to green, gives the leadership to some other car in charge and continues its drive. If there are no more cars, the process will be established on the same way, when next few cars come to the intersection. In the case of just one car in the intersections, the status of the intersections for this car is green. Otherwise, if there are more than on car, a new leader must be elected to act as traffic light and maintain the order in the intersection.

This approach has many opportunities for the transportation in the future, but also many issues. For the first, it could speed-up traffic in the congested urban areas, reduce CO_2 emission, reduce travel time and number of dead and injured people in the car accidents, reduce time of reaction for emergency and rescue vehicles (ambulance, fire department, police, security forces) automatically giving priority of passage through intersections to these vehicles.

On the other side, there is also number of issues and problems to solve before this technology is going to be applied in the real environment. For example, how to manage behaviour of

pedestrians and bicycles in the traffic, without VTL equipment. What if less than 100% of vehicles is equipped with VTL devices? What to do with existing infrastructure? How to guarantee safety on these roads, and how to determinate who is guilty in case of car accidence? There are also lot of questions of security and privacy – protection against malicious attacks, takeover of control or stealing data.

Both of them, opportunities and issues, were in the scope of many researches in last decade, and these researches will be collected, analysed and classified in next sections.

3 METHODOLOGY

To get the wanted results, it will be used method of systematic mapping study (Petersen et al., 2015), with nest steps: (1) research questions, (2) search in the databases, (3) study selection and quality assessment, (4) keywording using abstracts, and (5) data extraction and mapping of papers.

3.1 Research questions

Research questions will be answered after analysis of papers in most important bibliographic and citation databases:

RQ1: How many papers on this topic was published in last 10 years?

RQ2: Who are most important researchers?

RQ3: Which are most popular sources and most citied papers?

3.2 Search and selection

The most important bibliographic and citation databases will be searched with keyword "virtual traffic lights", and excluded document type "Conference Review". These are: Scopus, Web of Science, IEEE Explore, ACM Digital Library and IET Inspec.

In the scope of this mapping will be included intersections of research papers only. It means, if some paper will be found in more than one database, it will be count just as source from the first database, and in others will be ignored.

3.3 Mapping of papers

All papers will be classified and described based on keywords and abstracts. Each paper will get its own ID key, and with this key and reference will be shown in the table. The table will contain title of the paper, reference, number of citations, class and maturity.

The document with all tables containing meta data of all papers is applied as an appendix to this paper, to make possible to repeat, replicate and reproduce this research with start criteria, and to get the same result.

4 RESULTS

After execution of query in chosen citation databases, most of published papers with the focus on VTL topic was found in the Scopus database. For that reason, Scopus is treated as a main research source, and records found in other databases are compared with Scopus, and just if are not found in Scopus, are count as an origin source paper. Also, IET Inspec database gave 0 results for our keyword, and it is not relevant for this document anymore, but it is shown in list with other results, because it was initially chosen as a research source.

4.1 RQ1 - Papers published in last 10 years

Numbers of papers received by the query execution in selected databased are listed in Tab. 1. In this table, first column shows citation database, second column number of all records, and third column number of relevant papers regarding wanted criteria. Because most of papers were found in Scopus, last column shows the number of papers which are not contained in Scopus (except record of Scopus database).

Tab. 1 – Number of published papers on VTL. Source: own research

Source	Publications	Research	Relevant	Origin
Scopus	57	52	51	**51**
Web of Science	27	26	26	**1**
IEEE Xplore	27	27	27	**2**
ACM Digital Library	12	11	9	**6**
IET Inspec	0	0	0	**0**

On this point, it is possible to get the answer on the first research question – QR1: How many papers on this topic was published in last 10 years?

Tab. 2 – Number of relevant published papers on VTL in databases per year. Source: own research

Year	Scopus	WoS	IEEE Xplore	ACM DL	Total
2010	1	0	0	0	**1**
2011	0	0	1	1	**2**
2012	5	0	0	0	**5**
2013	6	0	0	2	**8**
2014	5	0	1	0	**6**
2015	5	1	0	1	**7**
2016	4	0	0	0	**4**
2017	3	0	0	0	**3**
2018	6	0	0	0	**6**
2019	7	0	0	2	**9**
2020	9	0	0	0	**9**
Total	**51**	**2**	**2**	**6**	**60**

In total, there are 60 found research papers with focus on Virtual Traffic Lights. Because this technology was introduced in 2010, all of them meet the criteria of last 10 years. Current year is not so relevant, because papers are not yet published. Most of papers is possible to find in the citation database Scopus.

4.2 RQ2 – Most important authors

Research question 2 is: Who are most important researchers on VTL? In these 60 papers, there are active 178 authors.

Fig. 2 – Number of papers on VTL and h-index of authors. Source: own research

Definitely best candidate for most important researcher on VTL topic is prof. Ozan K. Tonguz from Carnegie Mellon University, USA, with 9 papers on VTL, 250 papers in total, 7560 citation by 5658 documents and Scopus h-index 44. On the second place is Wantanee Viriyasitavat from Mahidol University, Thailand, with 7 papers on VTL and 38 papers in total, with 1104 citations by 968 document and Scopus h-index 16. The third place is Michel from Instituto de Telecommunicacies, Portugal with 6 papers on VTL and 12 papers in total, with 81 citations by 72 documents and Scopus h-index 5. Fourth place is Negin Fathollahnejad from Chalmers University of Technology, Sweden with 3 papers on VTL and 5 in total, 29 citations by 25 documents and Scopus h-index 3. Fifth place share another 24 authors with 2 papers, and rest of 150 authors have 1 paper each.

4.3 RQ3 – Best journals and conference papers

Research question 3 is: Which are most popular sources and most cities papers? Three best journals by citations and number of published papers on VTL are: "IEEE Transactions on Intelligent Transportations Systems" with 3 published papers and 319 citations in total, "IEEE Communications magazine" with 4 published papers and 63 citations in total, "ACM Transactions on Cyber-Physical Systems" with 2 papers and 7 citations in total.

The best conference paper is "Self-organized traffic control" (Ferreira et al., 2010), presented on 7th ACM International Workshop on Vehicular InterNETworking in Chicago, USA. Papers presented and published on this conference on VTL topic has 2 papers with 158 citations in total. A few best papers published on international conferences are shown in Tab. 3.

Tab. 3 – Best conference papers. Source: own research

Paper Nr.	Paper	Conference	Year	Cit.
P2	Ferreira et al., 2010	ACM International Workshop on Vehicular InterNETworking	2010	129
P5	Neudecker et al., 2012		2012	29
P12	Viriyasitavat & Tonguz, 2012	IEEE Vehicular Technology Conference, VTC Fall	2012	15
P23	Zhang et al., 2018		2018	9
P26	G. Wang et al., 2018		2017	5

4.4 Mapping of papers

In this section, Tab. 4 presents whole dataset of papers with key id, title, reference to the list, type of source (journal or conference), number of citations, class in which the paper was classified and maturity of paper – last two based on assessment of the author. There are 60 papers in total – 21 journal papers and 39 conference papers. They are divided to 5 basic classes, which should describe type and goal of paper: a study (survey), a concept proposal, an improvement proposal, an experiment, a simulation. In addition, there is also categorization by number of citations, into 5 classes: coloured in the column: ultrahigh (>50) = green, high (20-50) = orange, middle (10-20) = yellow, low (1-10) = blue and zero (0) = red.

Tab. 4 – Classification of papers. Source: own research

ID	Title	Ref.	Type	Class	Cit.	Cit. level
P1	Cooperative Intersection Management: A Survey	Chen & Englund, 2016	J	study	197	ultrahigh
P2	Self-organized traffic control	Ferreira et al., 2010	C	concept proposal	129	ultrahigh
P3	On the impact of virtual traffic lights on carbon emissions mitigation	Ferreira & D'Orey, 2012	J	simulation	81	ultrahigh
P4	A distributed virtual traffic light algorithm exploiting short range V2V communications	Bazzi et al., 2016	J	experiment	32	high

P5	Feasibility of virtual traffic lights in non-line-of-sight environments	Neudecker et al., 2012	C	study	29	high
P6	A self-organizing network approach to priority management at intersections	Tonguz & Viriyasitavat, 2016	J	experiment	24	high
P7	In-vehicle virtual traffic lights: A graphical user interface	Olaverri-Monreal et al., 2012	C	concept proposal	21	high
P8	Virtual traffic lights in partial deployment scenarios	Conceicao et al., 2013	C	concept proposal	18	middle
P9	A prototype of virtual traffic lights on android-based smartphones	Nakamurakare et al., 2013	C	experiment	16	middle
P10	A distributed algorithm for virtual traffic lights with IEEE 802.11p	Bazzi et al., 2014	C	concept proposal	15	middle
P11	On reliability analysis of leader election protocols for virtual traffic lights	Fathollahnejad et al., 2013	C	concept proposal	15	middle
P12	Priority management of emergency vehicles at intersections using self-organized traffic control	Viriyasitavat & Tonguz, 2012	C	concept proposal	15	middle
P13	Cloud-Driven Traffic Monitoring and Control Based on Smart Virtual Infrastructure	Hahanov et al., 2017	C	concept proposal	14	middle
P14	Virtual traffic lights: Managing intersections in the cloud	Munst et al., 2015	C	concept proposal	13	middle
P15	There is a Will, There is a Way: A New Mechanism for Traffic Control Based on VTL and VANET	Shi et al., 2015	C	concept proposal	13	middle
P16	Cloud-driven traffic control: Formal modeling and technical realization	Hahanov et al., 2015	C	concept proposal	12	middle
P17	A networking perspective on self-organizing intersection management	Sommer et al., 2014	C	improvement proposal	12	middle
P18	Implementing virtual traffic lights with partial penetration: A game-theoretic approach	Tonguz et al., 2014	J	concept proposal	10	low
P19	Accelerating the adoption of Virtual Traffic Lights through policy decisions	Viriyasitavat et al., 2013	C	improvement proposal	10	low
P20	Optimal virtual traffic light placement	Avin et al., 2012	C	improvement proposal	10	low
P21	Safety analysis of Virtual Traffic Lights	Yapp & Kornecki, 2015	C	study	9	low
P22	Virtual traffic lights+	Sinha et al., 2013	J	improvement proposal	9	low
P23	Virtual Traffic Lights: System Design and Implementation	Zhang et al., 2018	C	experiment	7	low
P24	Verification and evaluation of fail-safe Virtual Traffic Light applications	Neudecker et al., 2013	C	simulation	7	low
P25	Green wave-based virtual traffic light management scheme with VANETs	Chou et al., 2017	C	study	6	low
P26	TLB-VTL: 3-level buffer based virtual traffic light scheme for intelligent collaborative intersections	G. Wang et al., 2018	J	improvement proposal	5	low

P27	A probabilistic analysis of a leader election protocol for virtual traffic lights	Fathollahnejad et al., 2017	C	study	5	low
P28	Towards personal virtual traffic lights	Martins et al., 2019	J	improvement proposal	4	low
P29	Smart traffic lights over vehicular named data networking	Al-Qutwani & Wang, 2019	J	improvement proposal	4	low
P30	Intersection intelligence: Supporting urban platooning with virtual traffic lights over virtualized intersection-based routing	Saiáns-Vázquez et al., 2018	J	simulation	4	low
P31	Novel algorithm for leader election process in virtual traffic light protocol	Guo et al., 2019	J	improvement	3	low
P32	Harnessing Vehicular Broadcast Communications: DSRC-Actuated Traffic Control	Tonguz & Zhang, 2020	J	simulation	2	low
P33	Development of three-dimensional virtual PLC experiment model based on Unity3D	H. Wang et al., 2018	C	experiment	2	low
P34	Can electroencephalography improve road safety? An EEG-based study of driver's perception of traffic light signals in a virtual environment	Hoque & Tcheslavski, 2018	J	study	2	low
P35	A Distributed V2V-Based Virtual Traffic Light System	Rapelli et al., 2020	C	concept proposal	1	low
P36	Analyzing virtual traffic light using state machine in vehicular ad hoc network	Umang & Choudhary, 2018	C	study	1	low
P37	Local self-organization with strong privacy protection	Hanzlik et al., 2016	C	improvement proposal	1	low
P38	Self-organized intersection control management for motorized and non-motorized traffic	Ferreira et al., 2010	C	improvement proposal	1	low
P39	Study on cooperative vehicles infrastructure collision avoidance in unsignalized intersection using simplified conflict table	Wenhui et al., 2014	C	study	1	low
P40	A Prototype Model for Virtual Traffic Light Maintenance using AIS	Gohania & Lobiyal, 2020	C	concept proposal	0	zero
P41	Evaluation of Intersection Control Strategies Supported by Communication Infrastructure in Presence of Selfish Vehicles	Brizzi et al., 2020	C	study	0	zero
P42	Evaluation of push and pull communication models on a VANET with virtual traffic lights	Gama et al., 2020	J	study	0	zero
P43	Dynamic Prioritization of Emergency Vehicles for Self-Organizing Traffic using VTL+EV	Humagain & Sinha, 2020	C	concept proposal	0	zero
P44	STARC: Low-power Decentralized Coordination Primitive for Vehicular Ad-hoc Networks	Rathje et al., 2020	C	improvement proposal	0	zero
P45	A Framework for fog virtual traffic light system	Banikhalaf et al., 2020	J	concept proposal	0	zero

P46	Self-stabilizing maneuver negotiation: The case of virtual traffic lights	Casimiro et al., 2019	C	study	0	zero
P47	Spatial vector-based approach to the ERP analysis as applied to an EEG-based discrimination of traffic light signals	Sultana & Tcheslavski, 2019	J	concept proposal	0	zero
P48	A Novel Virtual Traffic Light Algorithm Based on V2V for Single Intersection in Vehicular Networks	Guo et al., 2019	C	concept proposal	0	zero
P49	Augmented traffic lights by means of cloud services	Dannheim et al., 2019	C	concept proposal	0	zero
P50	Clique-Based Traffic Control Strategy Using Vehicle-To-Vehicle Communication	Gee & Reynolds, 2019	C	simulation	0	zero
P51	Automotive networking and applications	Chen et al., 2014	J	study	0	zero
P52	On the Probability of Unsafe Disagreement in Group Formation Algorithms for Vehicular Ad hoc Networks	Fathollahnejad et al., 2015	C	concept proposal	4	low
P53	ITS for Sustainable Mobility: A Survey on Applications and Impact Assessment Tools	D'Orey & Ferreira, 2014	J	study	41	high
P54	Notice of Violation of IEEE Publication Principles: Biologically inspired solutions to fundamental transportation problems	Tonguz, 2011	J	concept proposal	29	high
P55	Quantify Self-Organized Storage Capacity in Supporting Infrastructure-less Transportation Operation	Hong et al., 2015	C	concept proposal	2	low
P56	Gulliver: a test-bed for developing, demonstrating and prototyping vehicular system	Pahlavan et al., 2011	C	concept proposal	7	low
P57	Parallel microscopic simulation of metropolitan-scale traffic	Fernandes et al., 2013	C	study	2	low
P58	The emerging applications of intelligent vehicular networks for traffic efficiency	Seredynski et al., 2013	C	study	12	middle
P59	Design and Analysis of Delay-Tolerant Intelligent Intersection Management	Zheng et al., 2019	J	simulation	5	low
P60	Combining Detection and Verification for Secure Vehicular Cooperation Groups	Asplund, 2019	J	concept proposal	0	zero

5 DISCUSSION

At the moment of first occurrence of the term Virtual Traffic Lights, this approach was pretty revolutionary approach to traffic problem, and the technology, as well as the traffic infrastructure and vehicles also, were probably not ready for such a solution. This can be a reason for just about 60 papers in 10 years with scope on VTL – either it was underestimated, or ahead of its time.

The citation of these papers is also not so high – 13 of 60 papers (21.6%) have zero citations, 27 papers (45%) have less of 11 citations, 11 papers (18.3%) have between 11 and 20 citations,

6 papers (10%) have between 21 and 50 citations, and just 3 papers (5%) have more than 50 citations. All papers together have 862 citations, where 452 times were cited papers published in journals, and 410 conference papers. It looks not so bad, but just three best cited papers have 339 citations – almost 40% (39.33%).

It could be changed with implementation of 5G mobile networks instead of present LTE – the speed and quantity of exchanged data will be drastically increased, and latency will be maximally reduced. Because of accent on electrical cars in next years, all these new vehicles will be implicitly smart, e.g. connected to some kind of cloud-based information backend. Thereby is open possibility to install and use some kind of VTL technology, especially if we want to have autonomous vehicles with level 3 or more.

Consequently, the interest of researcher for these field will be increased, and it is to expect more and more papers and studies on this topic. It will be necessary, because development of technology is very fast, and transition from manually operated combustion cars to autonomous electrical vehicles demands will be very increasing – it will be not possible without hundreds and thousands of researchers, simulations and experiments in different conditions. Initially, in simulated environments, then in real environment with strictly controlled conditions, and at the end in real conditions, with real human beings and all traffic participants – pedestrians, bicycles, motorcycles, scooters, buses, trucks, trams, etc.

It is expected that current research on VTL topic will evolve in parallel with technology and infrastructure development, and with more interest and more researchers, with many more possible solutions for incoming problems.

6 CONCLUSION

This work presents current status of research on topic Virtual Traffic Lights in last 10 years. All easily available and not hidden papers published in scientific journals or conferences in last decade, with focus on VTL technology, are involved in this research. Many papers have low maturity, but it does not mean that the topic is not interesting for researchers - it still has very much potential for improvement and future use in controlled or real environment, and it is very possible to read some more papers in the future.

Perhaps are these concepts lightly in front of its time, but with 5G and next generations of wireless communication it will be pretty different. And because the future of automotive for sure is electric, and not just electric than also data driven, the Vehicle-To-Everything communication will be very important. It is to expect some more improvement of this technology, or technology similar to VTL.

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INFLUENCE OF PANDEMIC ON MEDIUM ENTERPRISES IN ADDIS ABABA

Selamawit Assefa Redi, Petr Novák

Abstract

Medium enterprise is major part of entrepreneurship in Ethiopia by means of generating opportunities for employment, innovation idea, and supporting the country's economy. Developing countries such as Ethiopia must create a fertile ground for the medium enterprise to improve their productivity and competitiveness in the market specially during pandemic where uncertainty and susceptibility for the enterprise increase. Its highly important for Ethiopia to know the influence medium enterprise face during pandemics so that they can allocate the bounded resource they have to increase their performance. In the light of the current coronavirus crisis, medium enterprise faces a variety of challenges in a complex and fast-changing environment. To understand the challenge faced by medium enterprise in Addis Ababa during the COVID-19 the study used quantitative research. Convenience sampling was used to draw 100 medium enterprise for the study which were engaged in manufacturing sector. The study analysed 100 medium enterprise in Addis Ababa between 2019 and 2021 using descriptive statistics. The evidence suggests that the influence of the coronavirus crisis on medium manufacturing enterprise in Addis Ababa during the first year was very strong in terms of loss of monthly sales and net income and employment both permanent and temporary. Surprisingly, the government response to the COVID-19 was swift and efficient based on the tight resource available, instead of locking down the country as most countries did during the pandemic the Ethiopian government used partial lock down and used its limited resource on prevention.

Keywords: *Medium Enterprise, COVID-19, Manufacturing, Monthly Net Income, Employment*

1 INTRODUCTION

The COVID-19 pandemic and related restrictions are creating a global crisis, shaping the economic landscape and challenging entrepreneurs (Kuckertz et al., 2020; Brown & Rocha, 2020). While organizational resilience is crucial to keeping business afloat in these times, crisis-based entrepreneurship research that might inform resiliency cultivation has remained scarce (Doern et al., 2019; Linnenluecke, 2017; Monllor & Murphy, 2017; Bullough et al., 2014). With the COVID-19 crisis, early research results have suggested diminished venture capital availability, particularly for early-stage ventures (Brown & Rocha, 2020).

Most policy initiatives taken to protect economies during the COVID-19 crisis seem to target established corporations, existing industry sectors, and economies, and in doing so those measures aim to protect employment and the continuation of necessary economic activity. Currently, the focus is on protecting the present while the future of economic activity receives less attention. (Walsh & Cunningham, 2016)

Even in tranquil times, innovative start-ups face the challenge of newness and smallness (Stinchcombe, 1968) that put risk on their growth and continuation. This situation is likely to deteriorated in times of pandemics thus threatens to curtail an immense capability for innovation.

Entrepreneurs have also been quick to act to cut costs and seek support (Giones et al., 2020; Kuckertz et al., 2020; Thorgren & Williams, 2020), although entrepreneurial needs and policy responses have not always matched (Kuckertz et al., 2020), with for example entrepreneurs reluctant to take on additional loans (Thorgren & Williams, 2020). However, these studies have provided limited insights into the influence of the pandemic COVID-19 exerted on medium enterprise in Ethiopia calling for further research on creating new opportunities through innovation and revenue generating actions during the crisis (Kuckertz et al., 2020; Thorgren & Williams, 2020). Acting to create and pursue opportunities is at the heart of entrepreneurship. As Certo et al. (2009) state, "doing is a key theme running throughout the academic literature in entrepreneurship".

Entrepreneurial behaviour transcends present limitations and creatively repurposes resources (Becherer & Maurer, 1999; Baker & Nelson, 2005), with a growing literature on effectuation emphasizing how entrepreneurs engage in an active, flexible process focusing on experimentation and affordable losses to transform rather than adapt to existing environments (Chandler et al., 2009; Dew et al., 2008; Read et al., 2009).

Similarly, recent research highlights the role of experimentation in devising novel, successful business models (Bocken & Snihur, 2020; McDonald & Eisenhardt, 2020). Business models - defined as how organizations create, deliver and capture value (Teece, 2010; Zott et al., 2011; Sjodin et al., 2020; Schneider, 2019; McDonald & Eisenhardt, 2020) - reflect the realized strategy of organizations (Spieth et al., 2020; Casadesus-Masanell & Ricart, 2010) and the choices and actions entrepreneurs make in their offering, organization, networks and revenue models (McGrath, 2010; Spieth & Schneider, 2016; Schneckenberg et al., 2017; Bocken & Snihur, 2020).

The set of possible business models the venture would be able to experiment with using its current resources, capabilities and networks can be captured by its solution space, i.e. the range of potential solutions available to a venture, of which only a portion is actualized in any given moment (Macpherson et al., 2015; Goel & Pirolli, 1992; Bjorklund & Krueger, 2013). Solution space expansion, in turn, represents increased options and potential for business model innovation and can thus offer an additional pathway to organizational resilience.

To stem the spread of COVID-19, Ethiopia instituted a partial lockdown on the 16th of March 2020, followed by a State of Emergency on 8th April. For a country with very few private enterprises and the lowest entrepreneurial activity in Africa, this cause problem, especially for the women and youth depending on income and jobs from the 1.5 million MSMEs in the country (Entrepreneurship Development Centre, 2020).

This study aims to outline influence of COVID-19 that are faced by medium manufacturing entrepreneurs' in Addis Ababa by considering employment loss, monthly sales, and net income losses and identify the measures taken by the government to reduce those influences. In fulfilling the research aim three research question were set:

RQ1. How were medium sized enterprise employment in Addis Ababa affected by COVID-19?

RQ2. How were medium sized manufacturing enterprise monthly sales and monthly net income in Addis Ababa affected by COVID-19?

RQ3. What was the copying mechanism the Ethiopian government used to mitigate COVID-19 influence on medium manufacturing enterprise in Addis Ababa?

2 LITERATURE REVIEW

There has been a long history of fear of pandemic outbreaks. The discussion has not focused on whether there will be an outbreak, but when new outbreaks will happen (Stöhr & Esveld, 2004). The events leading to influenza pandemics are recurring biological phenomena and cannot realistically be prevented. Pandemics seem to occur at 10–50- year intervals because of the emergence of new virus subtypes from virus re-assortment (Potter, 2001).

As the global population increases and we need to live closer to animals, it is likely that the transfer of new viruses to the human population will occur even more frequently. All our society can do is take preventive measures so that we are able to act quickly once we suspect an outbreak. We should also try to learn from the consequences of pandemic outbreaks to prepare our societies for if—and, more likely, when—this happens again. As we are in the middle of a pandemic outbreak, it is very difficult to estimate its long-term effects. Although society has been hit by several pandemics in the past, it is difficult to estimate the long-term economic, behavioural, or societal consequences as these aspects have not been studied to a great extent in the past. The limited studies that do exist indicate that the major historical pandemics of the last millennium have typically been associated with subsequent low returns on assets (Jorda et al., 2021).

For a period after a pandemic, we tend to become less interested in investing and more interested in saving our capital, resulting in reduced economic growth. Given the current situation, in which saving capital means negative returns, it is not at all certain that we will be as conservative as we have been in the past. Behavioural changes related to pandemic outbreaks seem to relate to personal protection (Funk et al., 2009), such as the use of face masks, rather than general behaviour changes.

The COVID-19 pandemic outbreak has forced many businesses to close, leading to an unprecedented disruption of commerce in most industry sectors. Retailers and brands face many short-term challenges, such as those related to health and safety, the supply chain, the workforce, cash flow, consumer demand, sales, and marketing. However, successfully navigating these challenges will not guarantee a promising future, or any future at all. This is because once we get through this pandemic, we will emerge in a very different world compared to the one before the outbreak. Many markets, especially in the fields of tourism and hospitality, no longer exist. All organizational functions are intended to prioritize and optimize spending or postpone tasks that will not bring value in the current environment. Companies, especially start-ups, have implemented an indefinite hiring freeze. At the same time, online communication, online entertainment, and online shopping are seeing unprecedented growth (Donthu & Gustafsson, 2020).

Start-ups face immediate and substantial ramification of the pandemic outbreak especially in the form of depleted sales while fixed costs remain; a combination that threatens start-ups liquidity and long-term survival. Key partners, customers, and investors are themselves fully engaged in responding to the crisis and the uncertainty as to how the crisis will develop discourages any experimentation (Kuckertz et al., 2020), which in combination with barriers to accessing funding can adversely affect their onward growth trajectories (Bush et al., 2009).

According to International labor organization (2020) from the 1,000 companies surveyed from eight countries across four continents, 70% have had to shut down operations. Half of them have temporarily closed their business by following direct instructions from the authorities, while the other 50% have closed temporarily due to a reduction in orders, cases of staff COVID-19 infection.

2.1 Ethiopian Entrepreneurs During COVID-19

When an economy's degree of integration into the global financial system, fuel exports, and per capita gross national income (GNI) are considered Ethiopia, falls among the developing economies (Gorebet, 2020) but Ethiopia is also one of the fast growing economy (World Bank Group, 2018), and the second populous country in Africa (Goldsmith, 2019) which only has 1.5 million micro, small, medium in the country employed 4.5 million and generated 40.7 billion (birr) in monthly sales before the partial lockdown. Even before the pandemic hit the ground hard, these firms have laid off about 2.2 million and lost 28.5 billion in monthly sales revenue (Entrepreneurship Development Centre, 2020).

For a country with very few private enterprises per capita to begin with and the lowest entrepreneurial activity in Africa, this indicates trouble. The income and jobs from these enterprises, mostly owned by women and youth, sustain about 6.3 million household members. To make matters worse, 85% of the enterprises are micro, with utmost vulnerability to shocks. The country has implemented its first national entrepreneurship strategy in 2019 which will be implemented in the coming five years and should create more than 40 million job opportunities (Astatike, 2019).

2.2 Government Support to Minimize the Influence of the Pandemic.

Manufacturing sector by itself undergo complex process, compared with just a few decades ago, with subcomponents required to assemble a single final product sourced from several places across the globe. In times of pandemic where supply chain pass through disruption and chaos it makes it more difficult to for medium manufacturing enterprise to perform at their maximum capacity. Similarly, nearly 75%of companies reported supply chain disruptions in one form or the other due to coronavirus-related transportation restrictions, and the figure is expected to rise further over the course of time (Sengupta, 2020).

To boost their firm's financial capabilities (Williams et al., 2017) by gathering capital through internal measures and applying for government support. However, with regard to government support, the study reported a perceived mismatch between the support service offered by government policy and their organizations characteristics, in that, start-ups are being excluded from policy measures because of not being bankable, or the support programs are beset by bureaucratic hurdles that outweigh the benefit.

On the contrary Oqubay (2020) reported that Ethiopia government launched several adjustments to its fiscal and monetary policies to tackle the influence COVID-19 will exsert on the country's economy. The government ensured a coherent response by maximizing coordination among public agencies at different levels. It also engaged in dialogue with the private sector to find workable solutions when global brands and buyers abandoned their suppliers in developing countries (Oqubay, 2020).

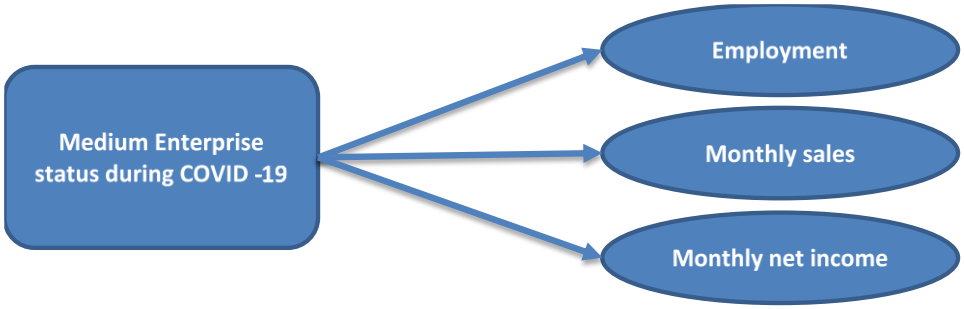

Fig. 1 – Conceptual framework. Source: own research

3 METHODOLOGY

Quantitative research was employed. Among the registered 850 medium enterprise in Addis Ababa 100 was selected using convenience sampling as a result of their convenience regarding location of their business and willingness to participate by providing data for the study. Because of the pandemic phone survey and interview with both close ended and open-ended questioners were used to collect the data. The period of the study was between 2019 to 2021. Both primary and secondary data were used and to analyse the data descriptive statistics were implemented.

4 RESULTS & DISCUSSION

4.1 Background of the Respondent

Among the respondent 70% of them were female while the average age was found to be 33 and 75% of them has taken short term business management training.

Tab. 1 – Demographic background of the respondent. Source: own research

Number of Medium enterprises	Female business owners	Average age of business owners age	Short term training on business management
100	70	33	75%

4.2 Status of Medium Manufacturing Enterprise in Addis Ababa Before and After COVID-19 in Terms of Employment, Monthly Sales and Net Income

Medium enterprises with high potentials for growth and on the path to joining the roster of large size ones that tend to create many jobs as opposed to micro enterprises that rarely hire more than two to three employees throughout their life cycles contributes greatly to the economy of the country. The loss of these enterprises therefore poses a far greater danger to the country's economic health.

Tab. 2 – Before pandemic status per enterprise (2019-2020). Source: own research

Permanent employment	Temporary employment	Total	Monthly Sales in Birr	Monthly net income in Birr
25	14	39	550,000	70,000

Before COVID-19 medium enterprise in Addis Ababa on average have 550,000 in monthly sales and 70,000 in monthly net income. However, following the partial lockdown monthly sales and net income have slumped by 86% and 83% respectively Similarly, Entrepreneurship Development Centre (2020), stated that starting from March 16 to April 24, 2020 it is estimated that about birr 2.3 billion is lost in monthly sales and birr 596.9 million is lost in net income and a total of 100,500 employees are already laid off from growing small enterprise in the country.

Furthermore, Donthu and Gustafsson (2020), stated that COVID-19 pandemic outbreak has forced many businesses to close, leading to an unprecedented disruption of commerce in most industry sectors.

Table 3 Below shows the influence the pandemic per enterprise among the surveyed 100 medium enterprises in Addis Ababa average data was used to construct the loss on employment and monthly sales and net income.

Tab. 3 – Average after pandemic status per enterprise (2020-2021). Source: own research

Average Permanent employment losses monthly	Average Temporary employment loss monthly	Total employment loss monthly	Average Monthly Sales in Birr	Average Monthly net income in Birr
10	6	16	80,000	12000

4.3 Government Support to Medium Manufacturing Enterprise During COVID-19

To identifying what the government support was for the medium manufacturing enterprise during COVID-19 open ended questions were used. The respondent were staffs from Federal Small and Medium Manufacturing Industry Agency. accelerated processing of VAT refunds to businesses, setting aside a 15-billion-birr ($450 million) liquidity facility for private banks to support their clients, especially businesses adversely affected by COVID-19, credit to micro and small and medium enterprises (SMEs), tax arrears forgiveness for 3,099 taxpayers with interest/penalties, tax exemption for importation of products related to curbing the outbreak.

The government's COVID-19 economic-support package is based on the principle of shared costs and sacrifices. For instance, the employers' confederation, labour unions, and the government agreed on a tripartite protocol to prevent layoffs during the crisis. Government subsidies have enabled manufacturing exporters to benefit from zero-cost rail transport and lower export logistics costs. And the government's new industrial-parks strategy envisages the establishment of manufacturing hubs to produce personal protective equipment for domestic and overseas markets.

5 CONCLUSION

In conclusion the study found out that medium enterprise in Addis Ababa has suffered heavily during the first year of the pandemic through reduced monthly sales and net income being unable to retain both their permanent and temporary employees. The selected 100 medium manufacturing enterprise has lost more than 80% of their monthly sales and net income as for the employment they have to let go of more than 50% of their employees.

The government response to the COVID-19 was swift and efficient based on the tight resource available, instead of locking down the country as most countries did during the pandemic the Ethiopian government used partial lock down and used its limited resource on prevention.

As a recommendation to further minimize the influence of the COVID-19 the study propose the Ethiopian government should check the spread of the pandemic through robust and effective preventive measures, facilitate capital to start businesses again or move over into newer business ventures, wage subsidy to the medium manufacturing enterprise to be able to keep employees on payroll.

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BIOLEACHING OF LITHIUM-ION BATTERY- REVIEW

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Abstract

The ubiquitous portable electronics and the use of electric vehicles lead to the creation of a pile of metric tons of used lithium-ion batteries, which usually end up in the trash. Batteries are valuable and recyclable, but due to technical, economic, and other factors, little is recycled today. Researchers are therefore looking for various options for cost-effective and environmentally sustainable strategies to address a wide range of lithium-ion batteries. The biological leaching process can be used to efficiently extract metals from used lithium-ion batteries (LIB) in an environmentally friendly manner using microorganisms such as chemolitotropic and acidophilic bacteria or fungi. These microorganisms carry out important reactions in the process that allow them to grow and multiply. The process of microbial leaching is demanding on the toxicity of metals to microorganisms. Their adaptation remains challenging and necessary to improve the efficiency of biological leaching. *Acidithiobacillus* bacteria and *Aspergillus* fungi help break down metals from used batteries. While bacteria oxidize ferrous iron and sulphur during biological leaching, fungi use the acids they form in their metabolic reactions to dissolve the metal. Biological leaching of metals from used LIB can reduce the impact of this waste on the environment, work with lower operating costs and water and energy consumption, production of less hazardous products.

Keywords: *Lithium-ion batteries, recycling, bioleaching, microorganisms, Acidithiobacillus*

1 INTRODUCTION

In the coming years, the global lithium market is expected to grow due to the expansion of lithium-ion batteries (LIBs) in electric and hybrid vehicles and in large energy storage industries, as well as in portable devices. Lithium is a vital raw material to produce currently available lithium-ion batteries and potential new generation batteries.

At present, 2/3 of the world's lithium production is extracted from brine, a process in which an average of half a million litres of brine per tons of lithium carbonate is evaporated. In addition, mining is chemically demanding, extremely slow and brings a lot of waste. Mining companies and academics are intensively looking for new technologies to recover lithium from brine (Flexer et al., 2018). The demand for lithium carbonate is expected to increase to 498,000 tons in 2025. It is assumed that lithium may already suffer from a shortage of supply on the commercial market after 2023. To avoid supply risk and reduce production costs, it is important to obtain lithium from all potential sources. At the end of their life, LIBs act as a secondary source for the recovery of precious metals and at the same time endanger the environment. Therefore, they need to be recycled properly to reap the economic benefits. Lithium, the lightest metal, has a strong electrochemical potential and low density. It has unique properties such as light components, high energy capacity, high voltage capacity, favourable discharge resistance, the ability to work through regeneration and withstands higher temperatures (Mohanty et al., 2021).

2 THEORETICAL BACKGROUND

2.1 Lithium-ion battery (LIB)

Lithium-ion battery (LIB) is a category of batteries of various chemicals including lithium as the primary cathode and electrolyte component. In addition to lithium, the materials used in LIB are cobalt and graphite (natural and artificial). The LIB consists of a cathode, an anode, an organic electrolyte, and a separator, which are laminated and compressed with each other to make electrical contact between them (Fig. 1). The electrolyte acts as an inert component stable to both cathode and anode surfaces (Steward et al., 2019).

It is a type of rechargeable battery commonly used in portable electronics (mobile phones, laptops, cameras) and electric vehicles. Rechargeable lithium batteries power about 60% of cell phones and about 90% of laptops worldwide (Marcinčáková et al., 2016). The growing consumption of LIB is increasing in the growth of various used LIBs in an ecosystem that contains hazardous chemicals, especially lithium and cobalt (Hartono et al., 2017). Used lithium-ion batteries are considered "hazardous waste" because they contain several toxic components, including cathodic materials containing oxides of heavy metals cobalt ($LiCoO_2$), manganese ($LiMn_2O_4$) or nickel ($LiNiO_2$) and electrolytes (Roy et al., 2021a), for example, $LiPF_6$, $LiBF_4$, $LiCF_3SO_3$ or Li ($SO_2CF_3)_2$. Lithium cobalt oxide ($LiCoO_2$) is used as a cathode in LIB due to its high specificity, energy density and service life (Biswal et al., 2018).

However, LIBs are a secondary source of metals that can be extracted and reused in many ways to reduce their potential environmental risks. They contain several precious metals (e.g. cobalt, lithium, nickel, manganese, copper) (Roy et al., 2021a; Boxall et al., 2018). Most of these batteries are landfilled or otherwise disposed of because environmental regulations regarding end-of-life batteries are not fully developed or implemented in many countries. However, with the growing production of lithium-ion batteries, interest in recycling is also growing (Jacoby, 2019).

Fig. 1 – Components of Lithium-Ion Battery. Source: Mohanty et al. (2021)

2.2 Recycling process

The lithium-ion battery is subject to various recycling processes, which include physical processes and chemical processes. Physical processes are pre-treatment methods, while extraction methods refer to chemical processes. LIBs are composed of heavy metals such as cobalt (5-20%), nickel (5-10%), lithium (5-7%), and organic matter (15%) and plastics (7%). Before disassembling the individual parts of the battery, it is necessary to discharge the battery to prevent short-circuiting or self-ignition of the battery. The cathode material is then separated from the battery and used by chemical processes to recover heavy metals. The methods used to

extract various metals, including Co and Li, are **pyrometallurgical** and **hydrometallurgical** methods, used alone or in combination.

Pyrometallurgical processes involve the direct melting of battery residues and enable the regeneration of high-value metals (Co and Ni) (Pagnanelli et al., 2016). After removing the individual cells, the battery is cleaned in a high temperature melting furnace. Plastics, organic solvents, and graphite are burned to supply energy for the recycling process. Then, metal species such as Co, Ni and Cu are reduced to alloys using a carbon-reducing agent (Wang et al., 2020).

The hydrometallurgical recycling process involves a chemical precipitation methodology that allows rare minerals to be recovered and delivered to battery manufacturers for reuse in the production of new batteries. Various active leaching agents such as H_2SO_4, HNO_3, HCl are used. Hydrogen peroxide (H_2O_2) is also used to accelerate the dissolution of metals or supercritical carbon dioxide (CO_2) (Ellis & Mirza, 2014). These methods require high energy, toxic chemicals and extreme physics-chemical conditions and ultimately release dangerous by-products for the environment. For example, the incineration of LIB waste leads to emissions of toxic furans and dioxins and is very energy-intensive (Boxall et al., 2018).

As an alternative to hydrometallurgical and pyrometallurgical methods for removing metals from various waste materials, including used batteries, a method called **biohydrometallurgy (bioleaching)** is used (Biswal et al., 2018).

3 METHODOLOGY-BIOLEACHING

Biohydrometallurgy means the dissolution of metals from insoluble ores, secondary wastes by various microorganisms, such as fungi and bacteria, with the ability to excrete inorganic or organic acids or cyanides that increase enzymatic oxidative reduction, proton-promoted mechanisms and/or ligand and complex formation. It uses chemicals, but also naturally occurring, acidophilic microorganisms oxidizing iron and sulphur to facilitate the transformation processes of metals that commonly occur in mining processes (Islam et al., 2020).

Bioleaching is the extraction of metals by the metabolic activity of bacteria (direct bioleaching) or metabolic compounds (indirect bioleaching). It is used for the removal of toxic metals, the recovery of metals from waste materials, the extraction of metals from low-quality raw materials (Pollmann et al., 2018).

The biological leaching process is a specialized bio hydrometallurgical process that uses the ability of microorganisms to obtain metals through the production of metabolites. The process is illustrated in Fig. 2 (Roy et al., 2021b).

The most common microorganisms in biological leaching are (Tab.1): (a) autotrophic, (b) heterotrophic (Chen et al., 2015), and (c) thermophilic bacteria and fungi (Işıldar et al., 2016).

The application of **acidophilic bioleaching microorganisms** to facilitate the recovery of metals from waste is promising because the leaching mechanisms of iron and sulphur-oxidizing microorganisms are well known and processes are generally considered to be more environmentally friendly than traditional mineral processing methods (Boxall et al., 2018). Furthermore, it is performed at low temperatures, requires less energy inputs and low operational costs, and emitted gases are less harmful to the environment (Kaksonen et al., 2018; Roy et al., 2021a).

The first research in this area was conducted in 2008 by Mishra et al. (2008) where they used mesophilic bacteria *Acidithiobacillus ferrooxidans* and obtained 65% and 10% cobalt and

lithium, respectively. Waste from LIBs is highly complex, polymetallic and acid-intensive, and studies have shown that inhibition of microbial growth occurs at low pulp densities (1–3%) (Mishra et al., 2008; Roy et al., 2021a).

Biological leaching of LIB waste is demanding due to low concentrations of iron and sulphur, which are the basic energy sources for the growth and activity of acidophilic microorganisms for biological leaching. Therefore, in order to facilitate the growth and activity of these microorganisms, it is necessary to supplement soluble ferrous iron and elemental sulphur and artificially improve the growth conditions (Boxall et al., 2018).

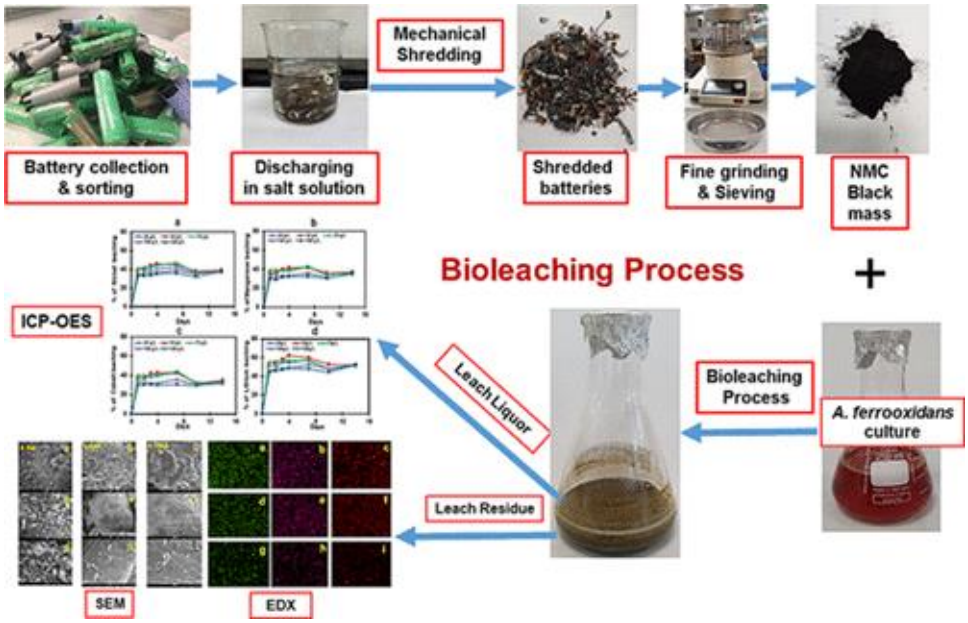

Fig. 2 – Bioleaching process. Source: Roy et al. (2021b)

The microorganisms most used to bioleach electronic waste are mesophilic aerobic and chemolithotroph microorganisms referred to as Fe / S oxides.

Bacteria of the genus ***Acidithiobacillus*** dominate key research in the field of biological leaching of electronic waste.

Acidithiobacillus ferrooxidans is a Gram-negative, non-sporulating bacterium with optimum growth temperature at 30°C and pH 2, but it can growth also at pH 1 or lower. It is abundant in natural environments associated with pyritic ore bodies, coal deposits, and their acidified drainages. *A. ferrooxidans* acts as a strong oxidizing agent to oxidize ferrous iron to ferric iron and reduce sulphur compounds, hydrogen, and formats to obtain energy in acidic environment. Under anaerobic conditions it can also reduce ferric ions and elemental sulphur and thus support the recycling of iron and sulphur compounds (Valdés et al., 2008). In the process of leaching cobalt and lithium from waste LIBs sulphuric acid is produced using this bacterium which is sufficient to leach metal ions from the waste batteries (Mohanty et al., 2021).

Acidithiobacillus thiooxidans oxidizes sulphur by reducing S^0 to SO_4^{2-} as an energy source (Eq. 1,2) (Pathak et al., 2017). These bacteria also consume CO_2 as a carbon source (Heydarian et al., 2018). For these types of bacteria, cheap elemental sulphur and pyrite or iron scrap can be used as an energy source instead of cheap iron sulphate heptahydrate (Fe^{2+}) (Xin et al., 2016; Ghassa et al., 2020).

Studies indicate an optimal process for the biological leaching of the lithium-ion battery using a mixed culture of *A. ferrooxidans* and *A. thiooxidans*. Various parameters such as pH, sulphur concentration, ferrous sulphate concentration is studied. The maximum yield is 99.2% Li,

50.4% Co and 89.4% Ni while maintaining the pH at 1.5 with optimization conditions of 36.7 g / l ferrous sulphate and 5.0 g / l sulphur (Heydarian et al., 2018).

Acidithiobacillus ferrooxidans and *Acidithiobacillus thiooxidans* (Fig. 3) can grow and utilize iron or elemental sulphur and produce iron ions or sulfuric acid, which are important in metal recovery (Eq. 2,3,4,5) (Pathak et al., 2017). However, they are not the only organisms that oxidize iron and sulphur (Yang et al., 2014).

$$2FeSO_4 + H_2SO_4 + 1/2O_2 \xrightarrow{\text{microorganisms}} Fe_2(SO_4)_3 + H_2O \quad (1)$$

$$S^0 + H_2O + 3/2O_2 \xrightarrow{\text{microorganisms}} H_2SO \quad (2)$$

$$H_2SO_4 + MeS \longrightarrow H_2S + MeSO4 \quad (3)$$

$$H_2SO_4 + MeS \longrightarrow H_2O + MeSO_4 \quad (4)$$

$$Fe_2(SO_4)_3 + MeS + H_2O + 3/2O_2 \longrightarrow ME^{++} + SO_4^{--} + 2FeSO_4 + H_2SO_4 \quad (5)$$

Fig. 3 – Acidithiobacillus ferrooxidans and Acidithiobacillus thiooxidans. Source: own research

Aspergillus is a genus of fungi that includes more than 180 recognized species. It can adapt to any environment with a high concentration of oxygen. Fungi have advantages over bacterial leaching, including the ability to grow over a wide pH range, tolerate toxic materials, and operate at faster leaching rates. The most famous fungus is ***Aspergillus niger*** (Fig.4), which produces more than 99% of the production of citric acid worldwide. In addition to citric acid fermentation, the fungus is also used to produce many important industrial enzymes, such as amylases, glucosidases, proteases, cellulases, hemicelluloses and xylanases (López-Gómez & Pérez-Rivero, 2019). The mechanism of biological leaching of *A. niger* is related to its excretion of low molecular weight metabolites, including organic acids (Bahaloo-Horeh & Mousavi, 2017)

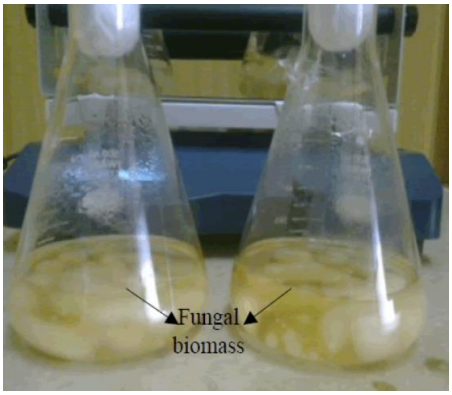

Fig. 4 – Aspergillus niger. Source: (Nida & Namra, 2016)

Tab. 1 – Microorganisms used in bioleaching of LIB waste. Source: own research

Microorganisms	**LIB waste**	**The elements present in the black mass**	**Black mass**	**References**
Acidithiobacillus Ferrooxidans	LIB	Ni 15.96% Mn 9.10% Co 7.44% Li 5.16% Cu 2.82% Al 0.62% Fe 0.97%	Ni 90% Mn 92% Co 82% Li 89%	(Roy et al., 2021b)
Acidithiobacillus caldus, Leptospirillum ferriphilum, Sulfobacillus spp.A Ferroplasma spp.	LIB	Co 31.18% Ni 9.07% Li 7.04% Mn 5.02% Fe 0.93% Al 0.61% P 0.42% Cu 0.22%	Co 99.9% Ni 99.7% Li 84%	(Ghassa et al., 2020)
Acidithiobacillus ferrooxidans Acidithiobacillus thiooxidans	LIBs	C 42.8% Co 30.4% Li 10.3% Ni 8.2% Mn 5.2% Fe 2.2% Cu 0.6% Al 0.3%	Li 99.2% Co 50.4% Ni 89.4%	(Heydarian et al., 2018)
	Lepidolit	Li 9%	Li 8.8%	(Sedlakova-Kadukova et al., 2020)
Rhodotorula mucilaginosa	Lepidolit	Li 1.1%	Li 92%	(Sedlakova-Kadukova et al., 2020)
Aspergillus niger	Waste LIBs	Mn 22.0% Co 17.1% Al 9.4% Cu 6.6% Ni 2.8%	Li 100% Co 64% Ni 54% Mn 77%	(Bahaloo-Horeh & Mousavi, 2017; Bahaloo-Horeh et al., 2016)
	Lepidolit	Li 0.2%	Li 77%	(Sedlakova-Kadukova et al., 2020)
	Lithium-ion mobile phone batteries	Li 2.22% Ni 2.26% Cu 5.93% Al 9.12% Co 6.54% Mn 21.31%	Li 100% Cu 94% Mn 72% Al 62% Ni 45% Co 38%	(Bahaloo-Horeh et al., 2018)

Biological leaching is also associated with possible toxic effects of metal ions on the microorganisms used, especially for mesophilic *Acidithiobacilli*. Toxic effects are observed at higher concentrations and therefore the identification of a suitable concentration of these metal ions is very important for the development of a successful biological leaching process (Pathak et al., 2017).

4 RESULTS

The advantage of the battery recycling process is the return of the value of metals from the used LIBs. After (bio) leaching, a solution containing various ions is obtained, which can be processed into various valuable products, such as metals, chemicals, new electrode materials and other functional materials (Huang et al., 2018).

5 DISCUSSION

5.1 Environmental impacts of LIBs

Despite the advantages of lithium-ion batteries and high economic gain, lithium can be a limited resource (Wagner, 2021).

For the production of one tons of lithium, 250 tons of bottom (a pyroxene mineral consisting of lithium aluminium silicate, $LiAl(SiO_3)_2$ of post-mining mineral ore or 750 tons of mineral-rich brine are needed. The production of brine requires the drilling of a hole in the salt platform and the pumping of a mineral-rich solution to the surface. However, this mining activity depletes water levels. A ton of lithium requires 1,900 tons of water for extraction, which is consumed by evaporation (Harper et al., 2019).

Lithium mining has significant environmental and social impacts. Water pollution and depletion, soil damage and air contamination (Zacune, 2013). Lithium treatment can cause changes in freshwater availability and pollution, with serious consequences for human health and native biodiversity (Wagner, 2021).

Recycling lithium-ion batteries reduces the environmental damage resulting from landfilling. Also, recycling materials can significantly reduce energy consumption and emissions (e.g. CO_2, SO_x) (Bai et al., 2020).

6 CONCLUSION

Efficient ways to recycle batteries are proposed to achieve high efficiencies with minimal environmental impact. Although the literature shows that the efficiency of recycling using various methods is satisfactory, it is questionable whether laboratory technologies can be implemented on an industrial scale.

Recycling lithium-ion batteries is well placed to meet some of the demand for minerals, which will be increasingly needed to produce LIBs. The material obtained by recycling can be used to produce new batteries. The biological leaching process can be used to efficiently extract metals from used LIBs in an environmentally friendly manner.

In the bioleaching process, it is necessary to optimize influencing mechanisms and factors, such as pH and pulp density, concentration of sulphur and iron sulphate, or to achieve a resistance of microorganisms to LIB toxicity. Slow kinetics and long cultivation time of microorganisms are other drawbacks limiting the bioleaching of batteries. Optimization also requires the collection, transport, storage, and logistics of LIB in the pre-treatment phases.

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FOND MALÝCH PROJEKTOV

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INFLUENCE OF SURFACE ROUGHNESS ON SELECTED GEOMETRIC CHARACTERISTICS OF LASER BEAM WELDED JOINTS OF AW 2099 ALLOY

Filip Šugra, Milan Marônek, Jozef Bárta, Michaela Lopatková

Abstract

Al-Li alloys are used in various industries owing to their good mechanical and physical properties. However, one of the limiting factors of welding the aluminium alloys by laser beam is the high reflectivity of the beam and thus the reduced efficiency of the laser. Reduction of reflectivity can be achieved by increasing the surface roughness, which may have a beneficial effect on the absorption of the laser, resulting into affecting the weld bead dimensions. The paper deals with the analysis of the influence of surface roughness of welded materials on geometry of welded joints. Specimens of AW 2099 alloy 2099 with a thickness of 3 mm were milled to achieve different levels of roughness, and then laser welded. Characteristic dimensions of the welds (weld surface/root width) were measured. The obtained data were statistically analysed using the ANOVA method, in order to assess statistical significance of the influence of individual roughness parameters on the geometric characteristics of welds. The results of the analysis showed that, within the monitored range and surface roughness parameters, only the influence of roughness parameter Rq, Rz on the weld root width can be considered statistically significant.

Keywords: *Laser welding, AW 2099, geometric characteristics, ANOVA*

1 INTRODUCTION

Lithium is the lightest known metal element widely used in metallurgy. Lithium is an excellent alloying element in aluminium for several reasons. With every 1% addition of lithium, the alloy density decreases by about 3%, but the elastic modulus increases approximately by 6%, which is due to precipitation hardening in aluminium. Owing to the density reduction, the less material is needed and the total weight of component can be decreased. Because of these properties, aluminium alloys have found application in many industries, especially in the aerospace industry (Schlatter 2013; Martin, 1998).

On the other hand, aluminium alloys are known for their high laser beam reflectivity, which reduces the amount of energy absorbed during welding. One of the significant factors affecting the energy absorption is the material´s surface roughness. This parameter affects the input costs of production and also laser processing parameters, and thus the price of the entire production process (Obeidi et al., 2019).

2 LITERATURE REVIEW

The influence of material surface roughness on laser beam absorption has been discussed by not many authors. Regarding influence of surface roughness of aluminium alloys on laser beam welding this topic is discussed in literature even less.

Arata and Miyamoto (1972) in their study examined the CO_2 laser absorptivity by different metals (stainless steel AISI-304, aluminium, iron) of various surface roughness and setups (butt joint, bead on plate). It was noted that absorption level tended to increase with the surface roughness of the joint edge; however, when the surface melts, the absorption decreases to a

constant value, 13% for AISI-304, 3% for aluminium and 5% for iron (Arata & Miyamoto, 1972).

Covelli et al. (1988) performed analysis of CO_2 laser beam welding of butt joints of stainless steel with different edge surface roughness's obtained by different machining methods. The tests showed that the properties of the welds were not affected by the surface morphology of the joint edge (Covelli et al., 1988).

In their study, Sokolov and Salminen (2012) investigated the influence of joint edge surface roughness on weld quality and penetration depth. The characteristics were investigated on welded samples of two low-alloyed steels, S355 and St 3, of 20 mm in thickness with various joint edge surface roughness levels in butt joint configuration. They found that absorption of structural steel in butt-joint laser welding showed a significant dependence on the edge surface roughness at laser beam power more than 10 kW. The results show that, within the range Ra = 1.6 to 8 μm, the maximum penetration depths were achieved at a roughness level of Ra = 6.3 μm (Sokolov & Saliminen, 2012).

Obeidi et al. (2019) investigated the effect of surface roughness on the melt pool dimensions for laser processing of stainless steel and aluminium. Their study showed that the increased surface roughness leads to a considerable increase in the melt pool, which indicates an increase in the laser absorption. The correlation between the melt pool dimensions and the surface roughness is an almost linear relationship (Obeidi et al., 2019).

Regarding to lack of information concerning the influence of surface roughness of aluminium alloys on laser beam welded joints geometry the study of this phenomena was carried out in this paper.

3 MATERIALS AND THE METHODOLOGY OF EXPERIMENT

An aluminium-lithium alloy AW2099 with a thickness of 3 mm was used as an experimental material.

The surface of the material was milled at 12 spots of different milling parameters in order to achieve different levels of roughness. Then the surface roughness parameters (Ra, Rq, Rz) were measured. The most commonly used parameter of surface roughness (Ra) actually reflects the mean absolute value of the deviations forming the profile. The Ra value therefore cannot be quoted on the profile, since it is a mathematically determined value. Therefore, the profiles of different shape and different height specifications may show a similar or the same Ra value.

For better assessment of the profile, it is necessary to supplement this parameter with additional roughness characteristics, namely Rq and Rz (Görög & Samardžiová, 2016).

During milling, after removing 0.5 mm of the material thickness, the final thickness of the samples was 2.5 mm. Fig. 1 shows the milled material with the labelled samples.

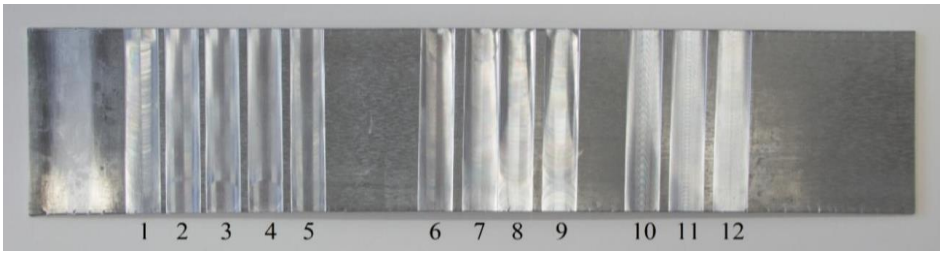

Fig. 1 – Milled material. Source: own research

Milling parameters and obtained surface roughness of the material are listed in Tab. 1.

Tab. 1 – Milling parameters and obtained surface roughness. Source: own research

Sample	a_p [mm]	v_c [m·min^{-1}]	n [rpm]	f_z [mm]	v_f [mm·min^{-1}]	Ra [µm]	Rq [µm]	Rz [µm]
1	0.5	500	7958	0.010	318	0.752	0.894	4.121
2	0.5	500	7958	0.100	3183	5.926	6.981	26.037
3	0.5	500	7958	0.150	4775	6.922	8.067	30.741
4	0.5	500	7958	0.200	6366	9.124	10.837	42.128
5	0.5	500	7958	0.050	1592	3.565	4.629	19.000
6	0.5	500	7958	0.083	2642	5.558	6.897	25.358
7	0.5	500	7958	0.083	2642	8.812	10.437	36.426
8	0.5	500	7958	0.045	1432	5.689	6.460	22.105
9	0.5	500	7958	0.040	1273	5.093	5.780	20.083
10	0.5	500	7958	0.220	7003	11.514	14.957	61.706
11	0.5	500	7958	0.240	7640	10.883	13.495	54.131
12	0.5	500	7958	0.175	5571	14.957	55.829	55.829

*Legend: **a_p** – depth of cut, **v_c** – cutting speed, **n** – revolutions per minute, **f_z** – feed per tooth, **v_f** – feed speed, **Ra** – arithmetical mean deviation of the assessed profile, **Rq** – root mean square deviation of the assessed profile **Rz** – maximum height of the profile*

After preparing the samples of different surface roughness, beads on plate welds were made. In an effort to eliminate inaccuracies associated with the weld edge preparation and the setup of the materials to be welded, the bead on plate was chosen instead of butt welding. Welding parameters are listed in Tab. 2, while the weld cross-section appearance is illustrated in Fig. 2.

Tab. 2 – Welding parameters. Source: own research

Laser power [W]	1700
Welding speed [mm·s^{-1}]	15
Shielding gas flow (argon) [l·min^{-1}]	30
Focal position [mm]	0

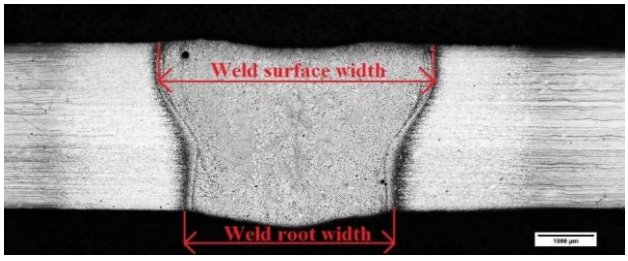

Fig. 2 – Weld cross section appearance. Source: own research

After welding, the widths of the surface and the root of welds were measured using a DinoLite digital microscope. Six measurements were performed on each weld, where the individual measured points were 10 mm apart. Fig. 3 shows the principle of measurement.

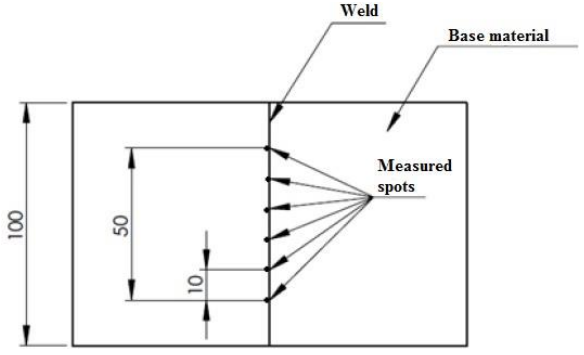

Fig. 3 – Scheme of measuring the width of surface and root of the weld. Source: own research

The mechanically machined sample is shown in Fig. 4. The shape of the surface and root of the weld bead of all samples were regular, no defects were visually identified, and the spatter of the weld metal was minimal.

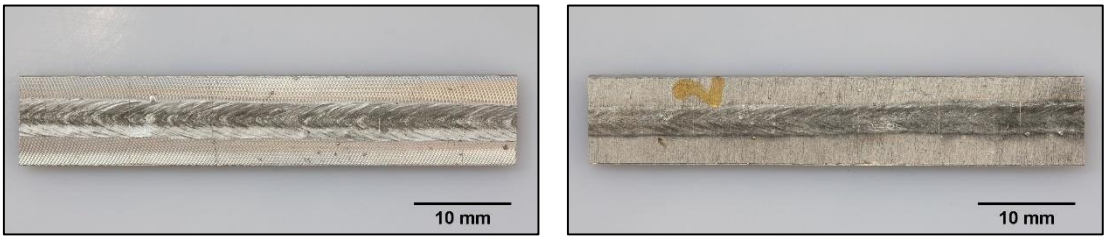

Fig. 4 – Appearance of the weld bead: left – surface, right – root. Source: own research

4 RESULTS

4.1 Correlation between weld surface width and surface roughness

After measuring the geometric dimensions of the welds, statistical analysis of variance (ANOVA) was performed in the GraphPad Prism 8 software package. Tab. 3 lists dimensions of the weld surface depending on the surface roughness of sample.

Tab. 3 – Weld surface width depending on surface roughness. Source: own research

Sample	Ra [µm]	Rq [µm]	Rz [µm]	Weld surface width [mm]						
				A	B	C	D	E	F	Average
1	0.752	0.894	4.121	4.46	4.75	4.61	4.77	4.63	4.39	**4.60**
2	5.926	6.981	26.037	4.29	4.41	4.41	3.88	4.26	4.08	**4.22**
3	6.922	8.067	30.741	4.21	3.93	4.06	3.84	4.15	3.82	**4.00**
4	9.124	10.837	42.128	4.41	4.31	4.35	4.38	4.41	4.02	**4.31**
5	3.565	4.629	19.000	4.12	4.30	4.34	4.45	4.29	4.09	**4.27**
6	5.858	6.897	25.358	4.29	4.18	4.27	4.38	4.35	4.34	**4.30**
7	8.812	10.437	36.426	4.72	4.98	4.75	4.93	4.45	4.10	**4.66**
8	5.689	6.460	22.105	4.39	4.39	4.70	4.30	4.51	4.17	**4.41**
9	5.093	5.780	20.083	4.47	4.29	4.22	4.27	4.42	4.35	**4.34**
10	11.514	14.957	61.706	4.39	4.25	4.45	4.46	4.39	4.25	**4.37**
11	10.883	13.495	54.131	4.29	4.34	4.50	4.47	4.49	4.34	**4.41**
12	14.797	16.946	55.829	4.38	4.33	4.37	4.45	4.50	4.50	**4.42**

Tab. 4 lists evaluation of statistical analysis of the correlation between the weld surface width and the material roughness.

Tab. 4 – Statistical analysis of the correlation between weld surface width and surface roughness. Source: own research

Surface roughness	Ra	Rq	Rz
P value	0.4072	0.8872	0.9113
Deviation from zero?	Not Significant	Not Significant	Not Significant

Graphical correlations between weld surface width and surface roughness is shown in Fig. 5.

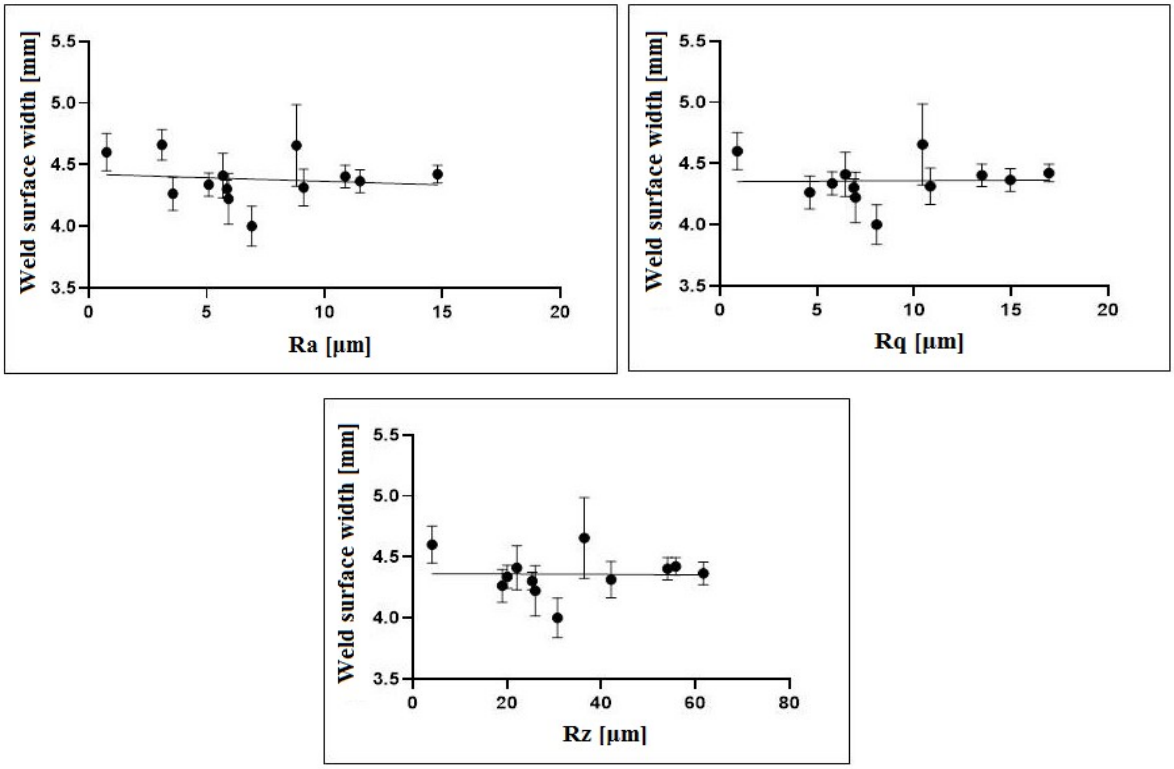

Fig. 5 – Graphical dependence of weld surface width on surface roughness. Source: own research

4.2 Correlation between weld root width and surface roughness

Tab. 5 lists dimensions of the weld root depending on the surface roughness of sample.

Tab. 5 – Weld root width depending on surface roughness. Source: own research

Sample	Ra [µm]	Rq [µm]	Rz [µm]	Weld root width [mm]						
				A	B	C	D	E	F	Average
brush	3.103	–	–	3.69	4.10	3.81	3.25	3.52	3.48	3.64
1	0.752	0.894	4.121	3.50	3.55	3.44	3.45	3.57	3.65	3.53
2	5.926	6.981	26.037	3.60	3.41	3.65	3.37	3.56	3.57	3.53
3	6.922	8.067	30.741	3.45	3.35	3.45	3.41	3.53	3.40	3.43
4	9.124	10.837	42.128	3.63	3.61	3.78	3.70	3.56	3.68	3.66
5	3.565	4.629	19.000	3.56	3.98	3.62	3.87	3.48	3.72	3.71
6	5.858	6.897	25.358	3.49	3.48	3.54	3.50	3.57	3.48	3.51
7	8.812	10.437	36.426	3.36	3.40	3.53	3.46	3.54	3.38	3.45
8	5.689	6.460	22.105	3.45	3.57	3.64	3.41	3.61	3.49	3.53
9	5.093	5.780	20.083	3.45	3.40	3.42	3.35	3.56	3.50	3.45
10	11.514	14.957	61.706	3.44	3.43	3.42	3.49	3.78	3.54	3.52
11	10.883	13.495	54.131	3.48	3.45	3.36	3.40	3.60	3.48	3.46
12	14.797	16.946	55.829	3.43	3.62	3.52	3.60	3.65	3.85	3.61

Tab. 6 lists evaluation of statistical analysis of the correlation between weld root width and material roughness.

Tab. 6 – Statistical analysis of the correlation between weld root width and surface roughness. Source: own research

Surface roughness	Ra	Rq	Rz
P value	0.6240	0.0011	0.0016
Deviation from zero?	Not Significant	Not Significant	Not Significant

Graphical correlations between weld root width and surface roughness is shown in Fig. 6.

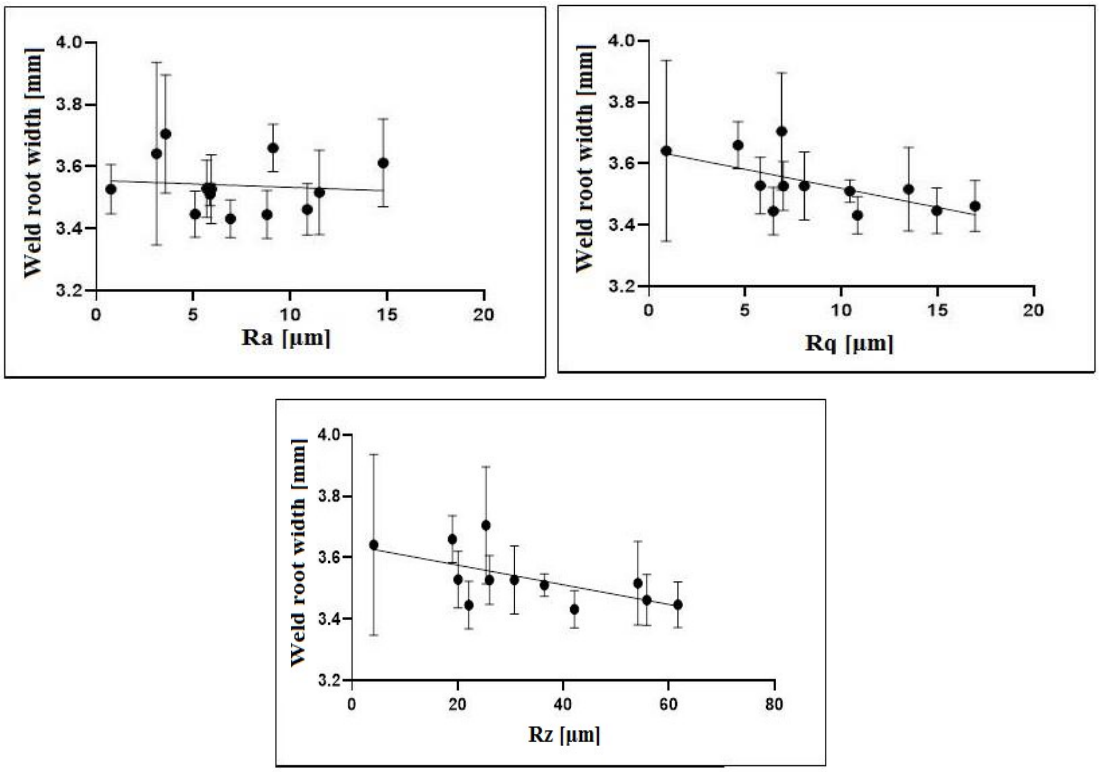

Fig. 6 – Graphical dependence of weld root width on surface roughness. Source: own research

5 DISCUSSION

5.1 Correlation between weld surface width and surface roughness

The P value (Tab. 4 & 6) of the result obtained from the sample is the probability that the observed dependence between the variables is entirely random, and thus this dependence does not actually exist. The higher level of significance, the lesser the observed dependence obtained from the examined data can be expected in the whole basic set. Thus, the observed significance value of 0.4072 (Tab. 4, Ra value) indicates that there is at most a 40.72% probability that the relationship between the variables found in the sample is entirely random. A result is considered statistically significant if the P value is less than 0.05. Tab. 4 suggests that none of the significance levels (P value) was less than 0.05. The obtained results (Tab. 4) show that the effect of surface roughness on width of weld surface is not statistically significant. This means that the results obtained from the examined data cannot be generalized to the entire basic set.

The data in Fig. 5 are presented as a mean ± standard deviation. It is obvious that the measured data show a significant variance in values, which proved their statistical evaluation as insignificant.

5.2 Correlation between weld root width and surface roughness

Tab. 6 indicates that the significance level (P value) for the Ra (arithmetical mean deviation of the assessed profile) was not less than 0.05. This means the effect of Ra roughness parameter on the weld root width value is not statistically significant. In the case of Rq (root mean square deviation of the assessed profile) and Rz (maximum height of the profile), the resulting P value was less than 0.05. The influence of the Rq and Rz roughness is statistically significant, and thus the obtained result is valid for the entire basic set.

In the case of Rq and Rz surface roughness parameters, statistical analysis showed these two values as statistically significant, but, owing to the large variance of the data, the correlation coefficient was small (0.1419 and 0.1334 respectively), and therefore the exact dependence of the weld root width on the surface roughness of the welded material could not be determined. These findings are contrary to the results of the authors (Obeidi et al., 2019; Sokolov & Salminen, 2012) who found the direct dependence between surface roughness and weld pool dimensions as well as depth penetration. The differences may be caused by a laser type used (CO_2 vs Yb:YAG disc laser), different welding regime (pulsed vs continuous) as well as diverse power beam density.

6 CONCLUSION

Statistical analysis of variance (ANOVA) did not confirm the effect of any roughness parameter on the width of the weld surface within the examined range (Ra=0.752 to 14.797 μm, Rq=0.894 to 16.946 μm and Rz= 4.121 to 55.829 μm). The significance level indicating the probability of randomness of correlation between weld surface width and surface roughness was 0.4072 for Ra, 0.8872 for Rq and 0.9113 for Rz. The result considered statistically significant exhibits a P value of less than 0.05. In other words, there is a 40.72% probability for Ra, an 88.72% probability for Rq and a 91.13% probability for Rz that the relationship between the given roughness parameters and the weld surface width is entirely random, and therefore the surface roughness has no significant effect on the weld surface width.

The similar results were obtained from the statistical analysis of the correlation between the weld root width and the surface roughness parameter Ra. The significance level has a value of 0.624, and thus there is a 62.4% probability that the dependence between the monitored parameters is entirely random. The Ra parameter has no effect on the weld root width.

On the contrary, for the roughness parameter Rq and Rz, the significance level was 0.0011 and 0.0016 respectively. The found levels of significance were less than 0.05, which indicates that the effects of the roughness parameters Rq and Rz were statistically significant, thus proving/confirming the dependence of the weld root width on the material roughness. The obtained results are contradictory to the findings of the other authors, and therefore further research might be considered.

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ISOTHERMAL OXIDATION OF PVD NANOCOMPOSITE COATINGS

Patrik Šulhánek, Libor Ďuriška, Paulína Babincová, Ivona Černičková

Abstract

The aim of this paper was to investigate the oxidation resistance and morphological changes after isothermal annealing of a sandwich nanocomposite coating TiSiN/AlTiSiN/TiSiN deposited on a high speed steel substrate. One sample was in as-deposited state, the other two were isothermally annealed in air at 800 and 1000°C. Morphology of the coatings was observed using scanning electron microscopy, chemical composition and presence of oxidation products was measured by energy-dispersive X-ray spectroscopy. It was found that with increasing annealing temperature the thickness of the oxide layer increased, and its morphology and chemical composition changed. After annealing at 800°C a thin oxide layer, probably containing titanium oxides, formed on the surface of the coating. Annealing at 1000°C resulted in the formation of a continuous oxide layer with a blade-like morphology. It consisted of two layers. The top oxide layer was rich in aluminium due to diffusion of aluminium towards the surface, therefore a presence of aluminium oxides can be expected. The lower oxide layer was probably formed by oxides of titanium and silicon. Also, in the top coating layer TiSiN a high amount of oxygen was measured, which means that the layer itself was oxidised. However, the oxidation did not reach all the way to the substrate and it can be concluded, that the substrate was well protected by the coating even at the highest temperature.

Keywords: *PVD coating, LARC technology, isothermal annealing, nanocomposite coating, oxide layer*

1 INTRODUCTION

In the process of machining there are various requirements that the tools need to meet. For example, the tool must have a good ductility to prevent fracture, and high hardness at the same time to decrease wear of the tool, and thus prolong its life time. However, these are contradictory requirements, because with increasing hardness the ductility decreases. This problem can be solved by depositing a hard coating on the surface of a ductile material. In addition to providing high hardness and wear resistance, the protective coatings also improve oxidation resistance and thermal stability of the tool. The coating also needs to have a good adhesion to the substrate (and in multilayer coatings also good adhesion between the individual layers), chemical stability and low coefficient of friction (Caliskan et al., 2017). First commercially used PVD (physical vapour deposition) coating was titanium nitride (TiN). Later, in the second generation of the PVD coatings aluminium was added to improve desirable properties and the TiAlN coating became the most widely used PVD coating for cutting tools. Crystal structure and mechanical and thermal properties of TiAlN coating strongly depend on the chemical composition. If the aluminium content is higher than that of titanium, the coating is AlTiN (Lungu, 2020). Over time the next generations of coatings appeared and the properties of the coating could be controlled by using different chemical compositions, different combinations of layers in multilayer coatings, adjusting thickness of the layers and other factors. One of the types of the coatings with excellent properties is a nanocomposite coating, which is a subject of this work (Caliskan et al., 2017).

2 THEORETICAL BACKGROUND

In the AlTiN system, aluminium atoms substitute the titanium atoms in the face-centred cubic crystal structure of TiN. Increasing the aluminium content (fraction of x in $Ti_{1-x}Al_xN$) to a value around 0.65 results in better tool performance. It happens due to distortion of the cubic crystal lattice, which increases the hardness and compressive stresses in the coating. Aluminium in the coating also increases the oxidation resistance thanks to the formation of protective Al_2O_3 oxide layer on the surface of the coating, which acts as an oxygen diffusion barrier. Similar effect can be achieved by adding silicon to TiN, which will result in the formation of protective layer consisting of oxides of silicon (SiO_2) (Babincová et al., 2020; Kohlscheen & Bareiss, 2018). Addition of silicon to the TiN, AlTiN or TiAlN coatings has an effect on their morphology, microstructure and overall properties by creating a nanocomposite structure. A nanocomposite structures consist of two or more phases coexisting in a very low volume. For example, TiAlSiN nanocomposite coating is formed by two phases – the nanocrystalline TiAlN grains embedded in amorphous Si_3N_4 matrix. As a result of this arrangement, these coatings can reach the hardness of more than 40 GPa. They are used for high performance machining and have excellent thermal stability, high oxidation and corrosion resistance and good tribological properties (Palacios et al., 2020; Strnad & Buhagiar, 2010). In the case of TiSiN and AlTiSiN nanocomposite coatings the crystals of TiN and AlTiN with the size of about 5÷10 nm, respectively, are embedded in the Si_3N_4 matrix (Babincová et al., 2020).

3 METHODOLOGY

In this work the oxidation resistance and morphology of a sandwich nanocomposite coating after isothermal annealing were investigated. The coatings were deposited on a HSS (high speed steel) substrate (HS6-5-2-5 EN ISO 4957) by cathodic arc evaporation using the LARC® (LAteral Rotating Cathode) technology PLATIT π^{80} + DLC (diamond-like carbon). Hardness of the substrate was 66 HRC. The microstructure of the substrate is shown in Fig. 1. EDX (energy dispersive X-ray spectroscopy) results showed that the matrix contained mainly iron, chromium and cobalt. The white particles embedded in the matrix are silicon, vanadium, molybdenum, chromium and tungsten carbides. Chemical composition of the substrate is listed in Tab. 1.

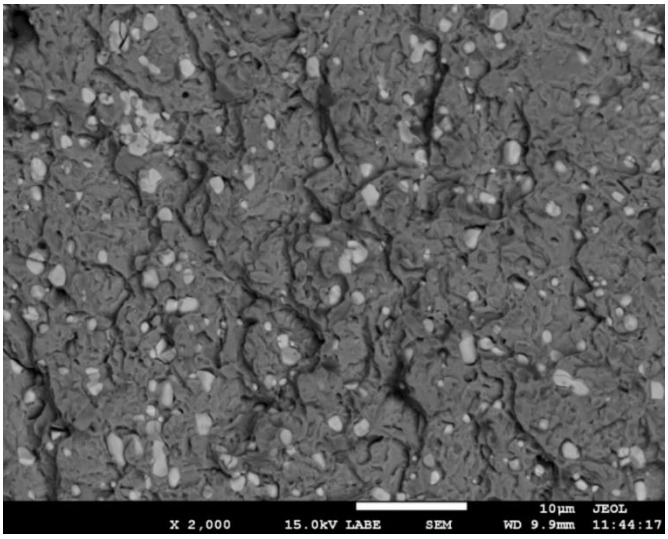

Fig. 1 – Microstructure of the HSS substrate. Source: own research

Tab. 1 – Chemical composition of the substrate HS6-5-2-5 EN ISO 4957. Source: EN ISO 4957:2000

Chemical element	C	Mn	Si	Cr	W
Content (wt. %)	0.87 – 0.95	max 0.40	max. 0.45	3.80 – 4.50	5.90 – 6.70
Chemical element	V	Mo	Co	P	S
Content (wt. %)	1.70 – 2.10	4.70 – 5.20	4.50 – 5.00	max 0.03	max 0.03

The substrate samples were in the form of discs with the diameter of 12 mm and their surface was polished and ultrasonically cleaned for 15 minutes in acetone. The coating consisted of three layers, as shown in the Fig. 2. The adhesive layer and the top functional layer were TiSiN layers with the thickness of 50 nm and 1µm, respectively. In between them there was a 2 µm thick functional nanocomposite AlTiSiN layer.

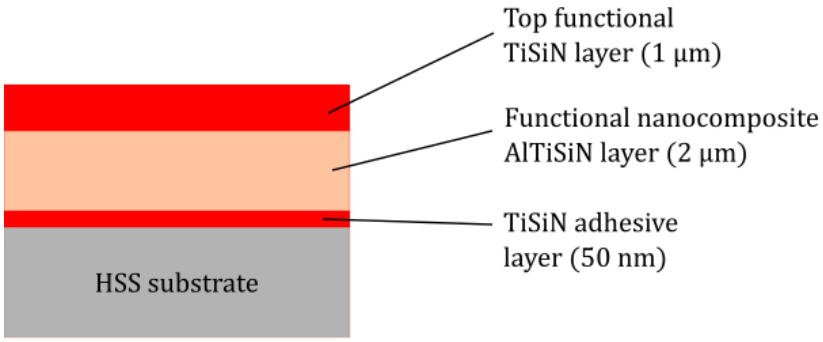

Fig. 2 – Schematic of the layers of the investigated coating. Source: own research

Three samples were investigated, one of them in as-deposited state, the other two after isothermal annealing at 800 and 1000°C in a laboratory furnace in air atmosphere for 1 hour, with a subsequent continuous cooling in air. The samples were then partially cut from the side of the substrate and broken in half.

In the investigation, the light microscopy, the scanning electron microscopy (SEM) and the energy dispersive X-ray spectroscopy (EDX) were used. The morphology of the fracture areas was observed by JEOL 7600F scanning electron microscope operating at the acceleration voltage of 15 kV in regimes of secondary electrons (SEI) or back-scattered electrons (BEI). Chemical composition of the coatings and the oxidation products on their surface was measured by EDX using Oxford Instruments X-max50 spectrometer including INCA software. Changes in element content from the substrate to the surface of the coating were measured by qualitative linescan EDX analysis.

4 RESULTS

4.1 Macro images of the samples

Fig. 3 shows macro images of the coating surfaces in as-deposited state and after annealing at different temperatures. A change in the colour of the surfaces was observed, which indicates that in the annealed samples oxidation occurred.

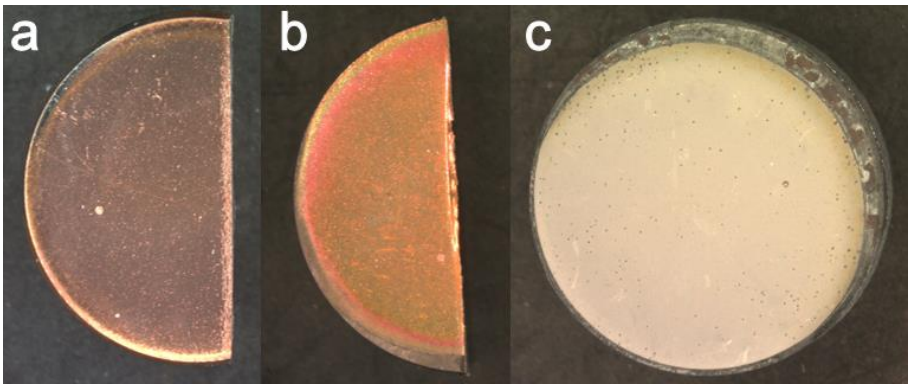

Fig. 3 – Macro images of the coating in as-deposited state (a), after annealing at 800°C (b) and after annealing at 1000°C (c). Source: own research

4.2 The coating in as-deposited state

On the surface of the coating macroparticles were observed using SEM, which are characteristic of the cathodic arc evaporation process. The fracture area of the as-deposited coating is shown in Fig. 4.

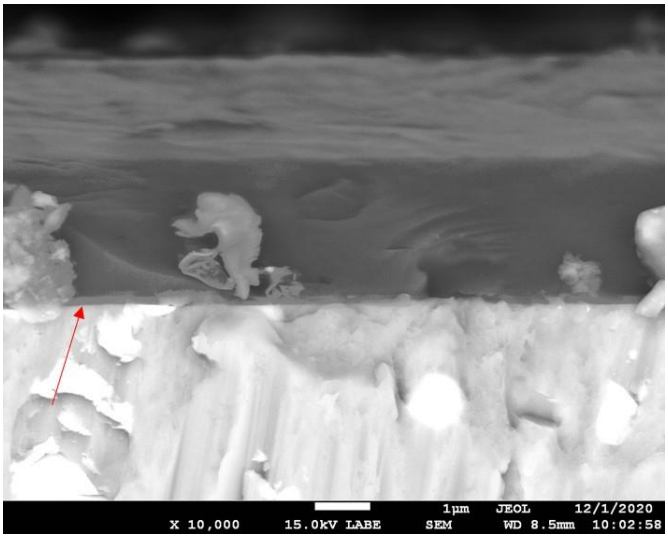

Fig. 4 – Fracture area of the coating in as-deposited state. Source: own research

All three individual layers of the coating can be recognised. The thin adhesive layer is marked with an arrow. The adhesive layer and the top functional layer are both TiSiN with higher titanium content, therefore they appear lighter in the image. On the other hand, the nanocomposite layer AlTiSiN contains more aluminium, which has lower atomic number than titanium, therefore the layer appears darker.

Chemical composition of the surface of the sample was measured by EDX. The results are listed in Tab. 2.

Tab. 2 – Chemical composition of the surface of the as-deposited coating measured by EDX. Source: own research

Chemical element	N	Al	Si	Ti	Fe
Content (at. %)	56.8	0.5	8.9	33.6	0.2

Fig. 5 shows EDX linescan of the fracture area of the as-deposited coating. It confirms the higher aluminium and lower titanium contents in the nanocomposite AlTiSiN layer. Also, the top layer, TiSiN, contains slightly more silicon and nitrogen than the AlTiSiN layer.

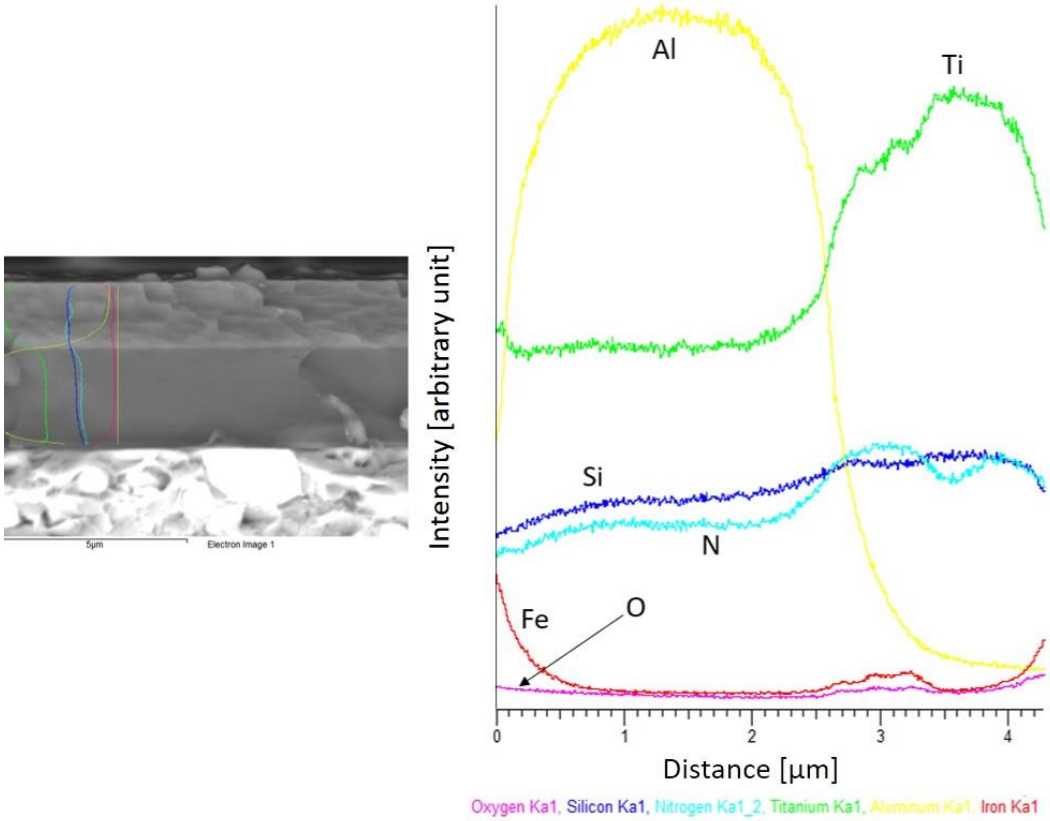

Fig. 5 – EDX linescan of fracture area of the coating in as-deposited state. Source: own research

4.3 The coating after annealing at 800°C

On the surface of the coating annealed at 800°C there are already signs of oxidation, especially at the sites with the defects in the coating. The fracture area in the Fig. 6 shows that a thin oxide layer formed on the surface.

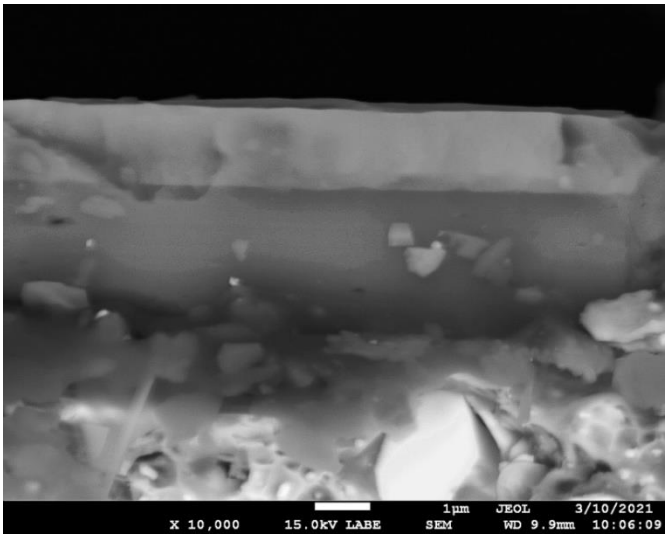

Fig. 6 – Fracture area of the coating after annealing at 800°C. Source: own research

Chemical composition of the surface of the sample measured by EDX is listed in Tab. 3.

Tab. 3 – Chemical composition of the surface of the coating after annealing at 800°C measured by EDX. Source: own research

Chemical element	N	O	Al	Si	Ti	Fe
Content (at. %)	17.2	54.0	0.3	6.0	22.4	0.1

Fig. 7 shows EDX linescan of the fracture area of the coating after annealing at 800°C. A significant increase in oxygen content was measured in the newly formed layer on the surface of the coating, indicating that the oxidation occurred.

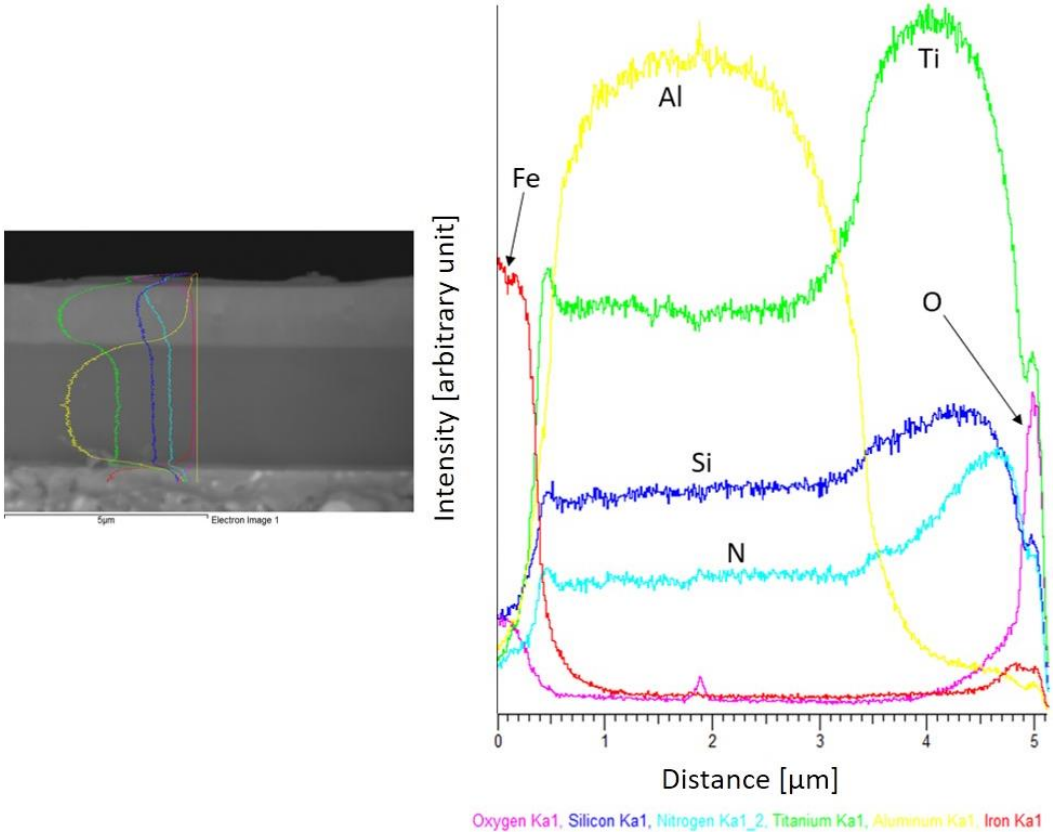

Fig. 7 – EDX linescan of fracture area of the coating after annealing at 800°C. Source: own research

4.4 The coating after annealing at 1000°C

After annealing at 1000°C the surface of the coating was covered with a continuous oxide layer with a blade-like morphology. The fracture area is shown in the Fig. 8, where the oxide layer with a varying thickness is visible.

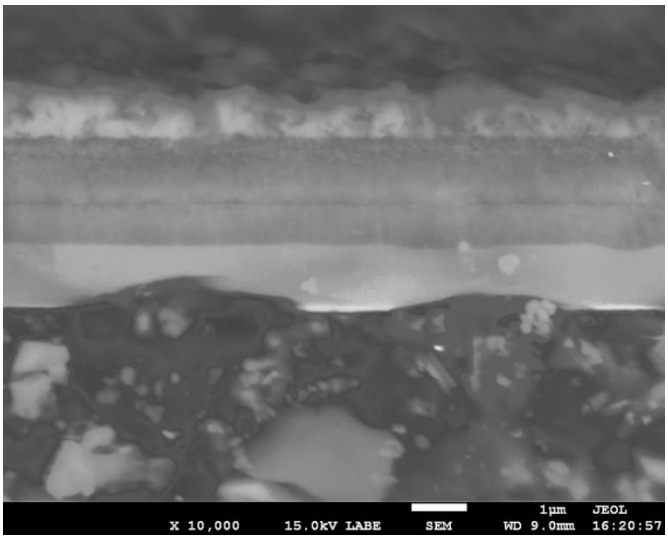

Fig. 8 – Fracture area of the coating after annealing at 1000°C. Source: own research

Chemical composition of the surface of the sample measured by EDX is listed in Tab. 4.

Tab. 4 – Chemical composition of the surface of the coating after annealing at 1000°C measured by EDX. Source: own research

Chemical element	N	O	Al	Si	Ti	Fe
Content (at. %)	0.0	70.9	10.3	1.3	17.2	0.3

Fig. 9 shows EDX linescan of the fracture area of the coating after annealing at 1000°C. It can be seen that on the coating's surface there is an oxide layer rich in aluminium, but also that the top TiSiN layer and a part of AlTiSiN layer were oxidised, which is also clearly visible on the SEM image due to a darker colour. In this case the oxide layer was rich in titanium and silicon.

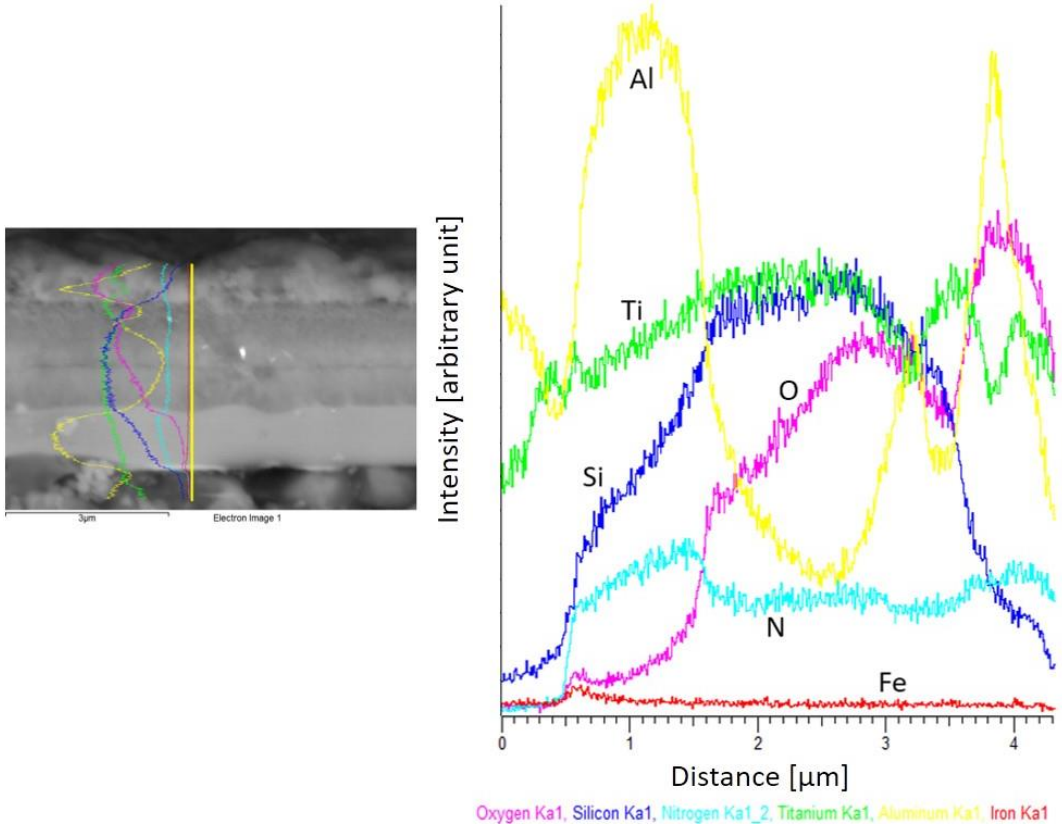

Fig. 9 – EDX linescan of fracture area of the coating after annealing at 1000°C. Source: own research

4.5 Overview of the layers

In the Fig. 10 there is an overview of the layer arrangement in fracture areas of the samples at each temperature, with the thickness of the layers measured in micrometres. In the as-deposited coating, there are the top Ti-Si-N layer, Al-Ti-Si-N layer and the thin Ti-Si-N adhesive layer with the thicknesses of 1.8 µm, 2.4 µm and 0.2 µm, respectively. In the sample annealed at 800°C, a thin titanium-rich oxide layer with the thickness of 0.3 µm formed on the coating's surface. The sample oxidised at 1000°C contained several layers. At the substrate – coating interface, there is a thin Ti-Si-N adhesive layer. Above the adhesive layer, there is the Al-Ti-Si-N layer, which was oxidised to almost a half of its original thickness. The oxygen-free Al-Ti-Si-N layer is visibly separated from the oxygen-containing layer. The oxidised part of the layer appears darker in the SEM image. Similarly, the whole top Ti-Si-N layer was oxidised as well, therefore it also appears darker. The oxygen-containing layer is called the Ti-Si-O-rich layer in Fig. 10, because it contains predominantly Ti, Si and O. It has a thickness of 2.9 µm. In the Ti-Si-O layer, the original separation of the Al-Ti-Si-N and Ti-Si-N layers is visible. Their interface appears as a very thin dark line. On the surface of the coating an aluminium-rich oxide layer with the thickness of about 0.8 µm can be seen.

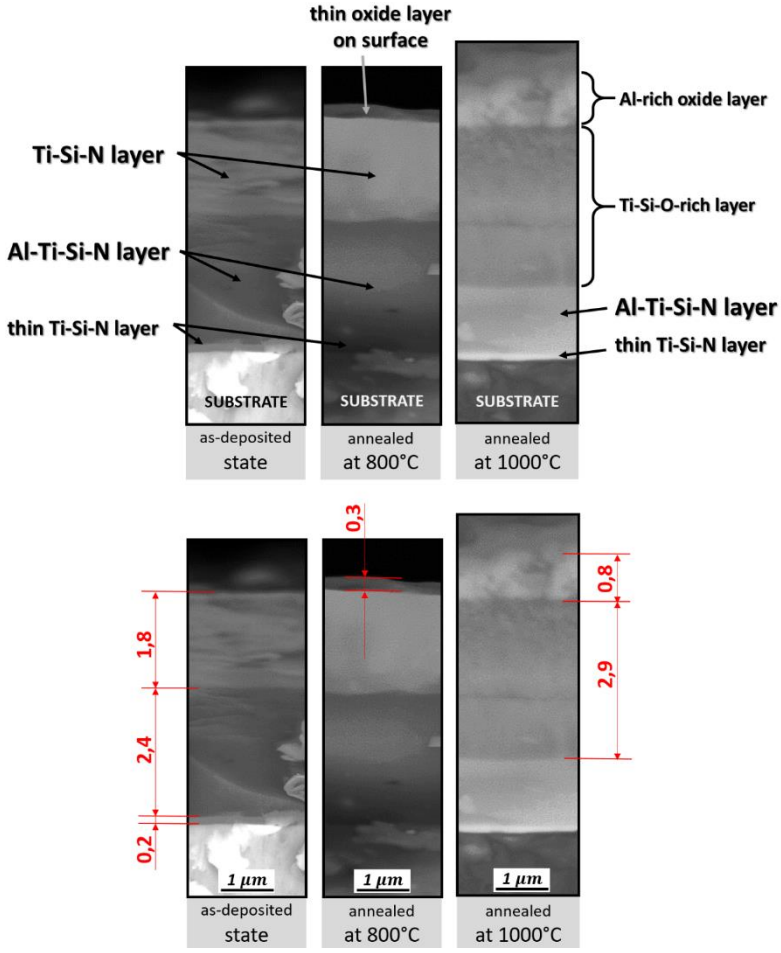

Fig. 10 – Overview of layer arrangement in fracture areas of the samples. The layer thickness was measured in micrometres. Source: own research

5 DISCUSSION

On the surface of the coating in as-deposited state a high content of nitrogen and titanium, and a low content of aluminium was measured by EDX (Fig. 10), because of the TiSiN top layer,

which is rich in titanium and nitrogen, and does not contain any aluminium. Since this sample was not annealed, the presence of oxygen was not detected.

The coating annealed at 800°C already showed signs of oxidation. A thin oxide layer formed on its surface, which was confirmed by SEM and EDX (Figs. 7 and 10). The oxygen content on the surface was 54 at. %. The oxide layer is most likely formed by titanium oxides. This result is comparable with the research of Babincová et al. (2020) where the same coating deposited on a different substrate (cemented carbide) was investigated. Moreover, the content of nitrogen, titanium and silicon decreased significantly in comparison with the coating in as-deposited state. Also, a slight increase in the oxygen content towards the substrate was recorded, which could be caused by a measurement error due to the uneven surface of the fracture area of this sample.

After annealing at 1000°C the surface of the coating was covered with a continuous oxide layer with a blade-like morphology and varying thickness (Figs. 9 and 10). The amount of oxygen on the surface measured by EDX increased to 71 at. %, which agrees with the result of Babincová et al. (2020). Moreover, there was not detected any nitrogen on the surface, and also the content of titanium and silicon decreased. On the contrary, the amount of aluminium significantly increased to 10.32 at. % due to diffusion of some aluminium from the AlTiSiN layer into the Al-rich oxide layer. In the research of Babincová et al. (2020), the oxide layer consisted of two different layers. Based on the fracture area image and the EDX linescan it seems that in our case the oxide layer also consists of two layers. The top layer is probably formed by oxides of aluminium and the layer below by oxides of titanium and silicon. Increased oxygen content was also measured in the top TiSiN layer and in a part of AlTiSiN layer, indicating that these layers were oxidised.

In the research of Babincová et al. (2020), where the cemented carbide was used as a substrate, globular substrate oxides of cobalt and tungsten occasionally formed on the surface of the annealed samples. Their presence is not desirable due to possibility of tearing off and damaging the layer during machining. In our case these oxides did not form, because the coatings were deposited on a different substrate – a high speed steel.

In another research (Hollerweger et al., 2014), authors studied thermal stability and oxidation resistance of arc-evaporated Ti-Al-Ta-N coatings, and found that the best oxidation resistance was obtained at 950°C in the coating with chemical composition Ti0.32Al0.60Ta0.08N. Also, Pfeiler et al. (2009) studied oxidation resistance of Ti-Al-Ta-N coatings as well, and found that the oxide scale consisted of the top Al-rich oxide layer, and Ti-Ta-rich sublayer. The top Al-rich oxide layer formed in our coating too, after annealing at 1000°C. Kuang et al. (2019) studied TiAlN-coated WC-Co hard metal tool tips after isothermal oxidation at 900°C, and the result was the formation of triple-layered oxide scale mainly consisting of the WO_3-concentrated outmost layer, the Al_2O_3-concentrated middle layer, and the TiO_2-concentrated inner layer. In another research (Xiao et al., 2018), authors studied oxidation behaviour of AlTiN and AlCrN-based multilayer coatings deposited on Al_2O_3 substrates by the arc ion plating. The oxidation temperatures were 800, 900 and 1000°C. It was found that AlTiN/TiSiN multilayer coating had worse oxidation resistance and thermal stability than AlCrN/TiSiN. Liu et al. (2019) studied high-temperature oxidation behaviour of AlTiSiN and AlCrSiN coatings deposited using arc ion plating and annealed in air at a temperature range of 600 – 1000°C for 2 hours. They found that the oxidation of AlTiSiN coatings started at 900°C and failed at 1000°C, and the oxidation of AlCrSiN coatings started at 800°C and kept stable till 1000°C, meaning that the AlCrSiN coating exhibits a better high-temperature oxidation resistance than the AlTiSiN coating. In the AlTiSiN coating at 1000°C formation and propagation of cracks were observed, while in our coating this did not occur.

6 CONCLUSION

It was found that with increasing annealing temperature the thickness of the oxide layer increased and the content of nitrogen, titanium and silicon on the surface of the coating decreased. On the other hand, at the highest annealing temperature the content of aluminium significantly increased, since some amount of aluminium diffused into the oxide layer. After annealing at 1000°C the oxide layer consisted of two layers. The top TiSiN coating layer and a part of the AlTiSiN layer was also oxidised, but the coating did not peel off and thus the oxidation did not reach the substrate. It can be concluded that the coating protected the substrate sufficiently even at the highest temperature.

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THE FEASIBILITY OF A CONVOLUTIONAL NEURAL NETWORK IN THE DETECTION OF VARIABLE PHENOMENA IN ASTRONOMICAL OBSERVATIONS

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Abstract

Aims. Detection of changes in the variability of astrophysical phenomena is a very delicate and sometimes a precarious job. The variability of these changes can be very small; therefore, we propose a machine learning algorithm to detect these changes with a respectable probability. We will also evaluate the relevance of using this model in astronomical data analysis. *Methods.* We analysed optical Kepler data of KIC 008751494, a nova-like system, we extracted a 1591 day long light curve of the object from the Mikulski Archive for Space Telescopes (MAST). Afterwards we divided the light-curve into 10-day samples, subtracted the samples of gaps and zero values (132 samples remained) and calculated a periodogram for each part. We searched for characteristic frequencies and found a prominent one at $f \simeq 94.5$ μHz and a variability at $f \simeq 92$ μHz ranging from day 560-650. We created a heatmap to summarize these results into one form. We simulated three categories of a variable periodogram using *n-th* order polynomial fitting of a synthetic light-curve and trained a convolutional neural network (CNN) on these data to detect the variability. *Results.* The trained neural network successfully detected the small variability in a real image data with a 99.65% probability. Therefore, we can say that CNNs can be a good tool to classify and detect small details in image-based astronomical data.

Keywords: *convolutional neural network, kic008751494, Lomb-Scargle, simulation*

1 INTRODUCTION

Nova is an astronomical event caused by an interaction involving two cataclysmic variables (CVs). The main star is a white dwarf (either with or without an accreting disc) accreting mass from a companion star. The accretion process accumulates mass until a certain point the mass can no longer be contained within the host star, and this leads to an event in which the white dwarf ejects his "envelope" of mass in an outburst.

We will analyse a nova-like system meaning that the outburst of the main star was not seen, nor recorded. These systems show high accretion rate meaning they are in a bright state and good candidates to study accretion processes. We will draw our attention to a phenomenon occurring during the accretion process called flickering which does not have a strict period of occurrence. Flickering can also be a signal for a significant event called superhump with a variable period causing a change in the system's brightness. The variability of these changes can be significant or, like in our case, with a lower magnitude.

We reproduced and simulated this phenomenon based on a real light curve obtained from Kepler telescope's optical data. Three categories of variabilities were simulated in total. Period with no variability (constant frequency), with a variability occurring on the whole curve (based on the order of the polynomial fit used in the simulation process), and no period or variability in the synthetic light curve (white noise). These data will serve as a training set to a machine learning model with the goal to detect these forms of variability in the light curves of nova-like systems. The variabilities will be shown on a heatmap.

We will examine uses of deep learning for image classification and use a CNN as our machine learning model. We will work in the computing environment of Matlab. There can be found pre-trained CNNs. These have a pre-built architecture and are trained to classify images from more than 1000 categories. We will train and optimize it for our purpose. After that, we will evaluate the network performance on real data. We will discuss the use of knowledge transfer to create three more different machine learning models which will be based on a different nova-like system also clearly showing similar quasi-periodic oscillations depicting physical origin.

2 LITERATURE REVIEW

In our work we analysed the nova-like system called KIC 008751494 from the Kepler space telescope. The telescope has two modes in which it records data. Short cadence, 59 s and long cadence, 29 min (Jenkins et al., 2010). The data are also with gaps and zero points due to the spacecraft entering an anomalous mode, these need to be eliminated to not interfere with our analysis of the researched phenomena. We believe there was a superhump event observed in the gathered data from our object of interest. Superhumps are variations in brightness with a slightly higher duration than the system's orbital period by a percentage. These were observed during super outbursts in some nova-like systems (Patterson & Richman, 1991). This change in brightness can be dim. Usual way to confirm their physical origin is to manually perform a time series analysis with appropriate methods e.g., fast Fourier transform for evenly spaced data, see Kozhevnikov (2007), Lomb-Scargle for unevenly spaced data see Schreiber (2007) or self-approach methods, see the work of Kozhevnikov (2004), Zurita et al. (2002) or Robinson et al. (1987).

The result of either of these methods is a periodogram showing the spectral density of the signal on a specific frequency range. Noise is also a permanent part of any astronomical data gathered from satellites. A convenient way to analyse variable period is using a heatmap. It shows a 3D graph of frequency with the power of the signal mapped to a colour, see Fig. 3 in Dobrotka et al. (2020).

To prove the physical origin of the found phenomena in either a heatmap or a periodogram, one must statistically define their confidence. This is usually done manually. Periodic data can be observed in almost all fields. Period detection methods have a considerable number of applications. For instance, the market prices change periodically as well as the product demand. Or, as in our case, the detection of superhumps in astronomical data. A periodicity is a pattern in a time series that occurs at regular time intervals. These are more difficult to detect due to their inconsistency. Every day the satellites provide an enormous data to process and analyse e.g., the HEASARC hosts data from 122 missions ranging 30 years (Myers, 2020). Therefore, we propose a machine learning algorithm to automatically detect and classify the variability in the period of any astronomical object.

An Artificial Neural Network (ANN) is a set of elementary neurons which are connected in a biologically inspired architecture and organized in several layers (Roy & Bhattacharya, 2021). An elementary neuron produces an output by performing a simple (nonlinear) operation on its input. A weight is added to every neuron together with a bias. These parameters are adjusted to the needs of classification of our problem during its training. Classification, where there is a discrete output, is one type of use of ANN, the other one is regression. In a regression problem e.g., price predicting, the output is continuous, and the goal is to find the best fit to the input data. There is no well-defined guide for selecting the ideal number of layers, values of weights and biases, only recommendations and empirical estimations. An ANN is a parallel computing model meaning the neurons in a layer work independently to produce their output. Every ANN

must have one input layer, an output layer and at least one hidden layer to learn to extract specific features from the input data.

The input signal of a neuron is multiplied by these weights. A summing function processes all the outputs in a layer. Next, an activation function to limit the amplitude of the output of the neurons is added. This output is then passed to a next layer (Yu et al., 2016). When a network classifies an image, the value of prediction is combined with the true classification in a function called the loss function. The goal of training a network is to minimize the loss function over a few passes of the training data. Each pass of the data is known as an epoch. After each epoch, the weights and biases are changed using gradient descent (GD) to minimize the loss function, thereby increasing the rate of correct classifications from the network. The rate at which GD changes the weights and biases is controlled by a variable called learning rate. This parameter is usually empirically chosen and modified in the training process (Roy & Bhattacharya, 2021).

With the development of ANNs, many powerful frameworks have been constructed with deep architectures for supervised learning. Unsupervised learning is the second method widely used to train ANN models, where the data is not organized into categories and the main goal of the algorithm is to find certain patterns in the data and divide it into categories. In this paper we will use deep architectures, specifically the CNNs to classify an image-based input with a supervised approach.

We will use a heatmap as a training input of the CNN depicting the period in the form of power of the signal in frequency domain. CNN is a special type of ANN intended to use with image-based input. The network extracts features from the image in an operation called convolution. In image classification problems, the descriptiveness and discriminative power of extracted features are critical to achieve a good classification performance. The features are usually represented as a vector and are used to train a classifier, in our case convolutional kernels.

In the current years, the research involving astronomy and machine learning is flourishing. Lukic et al. (2019) and Aniyan and Thorat (2017) used CNNs as a tool to detect radio sources e.g., galaxies in noisy observational radio telescope image data with more than 90% accuracy. The newly observed phenomena, gravitational lensing, can also be detected from image-based telescope data using a CNN. Davies et al. (2019) studied the accuracy of detecting lensing in simulated data using a pretrained CNN. The resulting accuracy of the CNN was about 77%. The percentage could be improved using more accurate simulations, as the CNN identified many false positive cases. CNNs can also be used as an image reconstruction tool. Flamary (2017) created a CNN with two convolutional layers and a Rectified Linear Unit (ReLU) activation to normalize the data rescaling them onto a specific range. The resulting reconstructed images were, as expected, good in both quality and correctness. In comparison to commonly used methods in astronomy, their approach proved that CNNs are both computationally efficient and competitive with other state of the art methods. Kimura et al. (2017) used five CNNs, each working with specific band-wise images. The input from these was then passed to an ANN which classified them. They also proved that multi-epoch training is more fruitful than single-epoch training with a 99.95% testing accuracy of the proposed model. There was also an attempt to detect binary black holes using CNNs as Gabbard et al. (2018) published in his paper. He used simulated gravitational-wave-based images of binary black holes to train a CNN with multiple convolutional layers. Using adaptive moment estimation with a fixed learning rate, they proved that a well-trained CNN can be a good asset in binary black hole detection and a close match to the methods used in classical astronomical approach. As previous authors mentioned, Gabbard et al. (2018) also declares that CNNs are more efficient in terms of computing time. In a recent research, Andersen et al. (2019) and Andersen et al. (2020) studied the possibility of using a CNN for wavefront sensing based on a

guide image obtained from telescopes. This type of images is obtained from telescopes observing the Earth's weather. They used a pretrained CNN called Inception using simulated datasets. The results in their research showed that this approach can bring potential improvements in comparison with telescopes of class 2-4m. Noise, or contaminants detection in astronomical images can be a complex task when using conventional methods. Paillassa et al. (2020) proposed two supervised CNN classifiers for the detection of the source of contaminants on astronomical images such as cosmic rays, hot pixels, nebulous features, diffraction spikes. Using a VGG-like architecture, CNNs trained for 30 epochs on 50000 images yielded an average accuracy of 97%. Mixing the types of contaminants did not impact the performance of the two created CNNs, proving that CNNs are able to find the necessary features in the training process based on the used training parameters. Supernovae outbursts detection is a highly used application of CNNs in astronomy. Cabrera-Vives et al. (2016) proposed a CNN trained on real observed image data of supernovae outbursts. The CNN contained one convolutional layer and a pooling layer. More than a million images were used in the training process. Also, more than a million different images were used in the testing process with a prediction accuracy of 99.32% compared to 98.89% accuracy with the same data but using a random forest model.

The mentioned works prove that a CNN can be a reliable tool in image-based detection of specific phenomena if the network is trained correctly. Our aim is to use a pretrained network with a built architecture, optimize it for our cause and determine whether CNNs provide a reliable method to classify variability of period in astronomical data. The network will be supervise trained on a simulated dataset. Compared with unsupervised neural network (Qing et al., 2013) the use of supervised learning yields better classification results (Love, 2002).

3 METHODOLOGY

The data we analysed represent an outburst of the nova-like system KIC 008751494. The optical data were taken by the Kepler satellite with a long cadence – 29 min. The data were retrieved from MAST under the mentioned name. The light curve was divided into 21 parts and a concatenation of these was needed to obtain the whole curve. Kepler data usually contain a lot of null points and gaps in its measurements. This is caused by the spacecraft itself when it enters anomalous mode to prevent overheating of the on-board electronics.

3.1 Data analysis

The first thing to do after cleaning our data is that we need to confirm the existence of the variability in the data. The light curve (Fig. 1) shows a gradual decline and an onset of a low state. The studied light curve is 1591 days long, after cleaning the data (from gaps and zero points) the final duration was 1320 days. We divided the light curve into equally spaced 10-day segments. A periodogram was calculated from each sample using the Lomb-Scargle algorithm (Lomb, 1976). This method is suitable for our unevenly spaced data, otherwise discrete Fourier transform would be an appropriate method to study our time series.

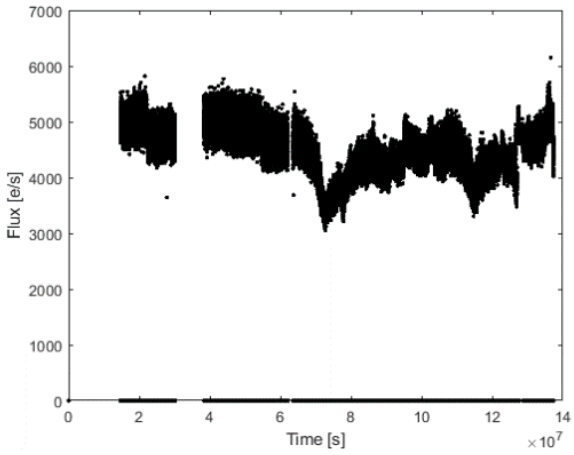

Fig. 1 – Light curve of KIC 008751494. Source: own research

Fig. 2(a) shows 132 grouped periodograms with a characteristic dominant frequency around $f \simeq 9$ mHz. There is also a harmonic component at $f \simeq 18.5$ mHz. But we believe this is caused by the noise in the data. The first frequency component is a mean power of all the frequencies in the periodogram.

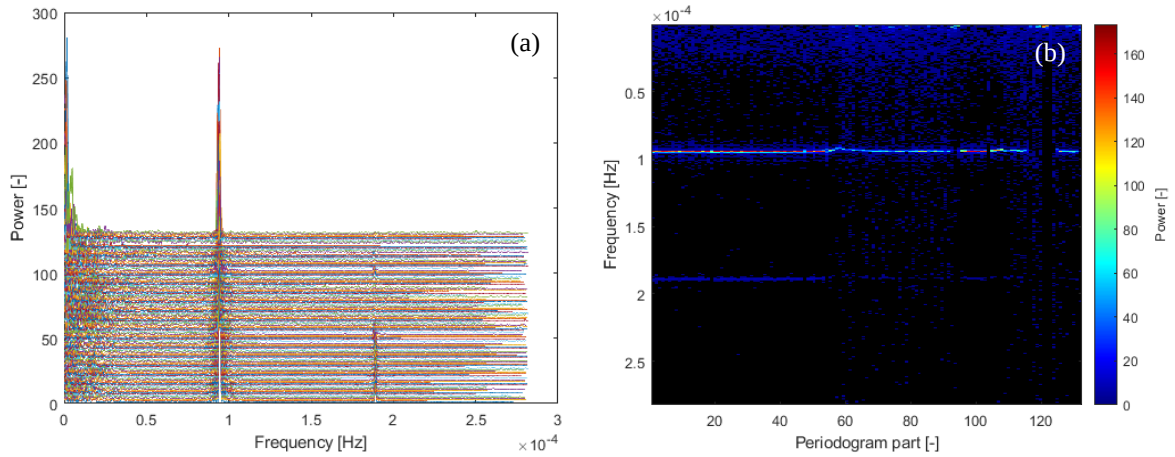

Fig. 2 – Grouped periodogram of KIC 008751494 (a, left); Heatmap of the grouped periodograms (b, right).

Source: own research

But we cannot precisely determine whether the dominant period is strict or variable, therefore we display the periodogram as a 3D map called heatmap. The x axis will be the number of periodograms, y axis will be the frequency domain and the power of the signal will be mapped to a colour. Each column will represent one periodogram from the group. Fig. 2(b) shows a heatmap of our data. We can clearly see a small hump on day 560-650, at $f \simeq 9$ mHz. This is our searched variability, or the so called superhump event. The harmonic frequency is also present. This will be the ground base for our next step, simulating this behaviour. Afterwards we use the simulated heatmaps as a training dataset for our CNN.

3.2 Simulations

Simulations are much needed especially in the field of astronomy. With them we can statistically confirm the existence of physical phenomena. Understanding of our analysed phenomena caused by non-equidistant sampling of data, determination of detection limits for future observations. These are some of the applications of simulated time series, in our case, the light curves. To create simulated heatmaps we need to perform a timing analysis of our real

data, which means to create a light curve similar to the observed one. The light curve will be represented by a function (1).

$$Y = c + A + sin(2\pi ft + \varphi) + kN \quad (1)$$

In (1) c depicts a vertical offset, A is an amplitude of the light curve, f is a desired dominant frequency, t is a time domain, φ a phase of the signal, N is a Gaussian noise multiplied by a factor of k. To simulate the variability, we chose an interval of parameters we will use. The Gauss noise has a strict mean μ and standard deviation σ of the distribution and is generated in an interval.

Tab. 1 – Simulation parameters. Source: own research

A	<10; 50>
φ	<10; 50>
f [Hz]	$<1 \cdot 10^{-5}; 1 \cdot 10^{-3}>$
k	<20; 130>
c	4198
μ	1
σ	<2; 20>

The Gauss noise is represented as a random variable with a normal distribution. The values in Tab. 1 were empirically estimated. To simulate the observed data, we created a variable period. We also wanted to simulate other types of variabilities to make the CNN more effective in classifying the variable period by learning to distinguish between variable and non-variable periods. Other types of variabilities will include constant frequency and white noise. The constant frequency will be represented by a single value of frequency used in (1) instead of an interval. The white noise was simulated only with the $k \cdot N$ relation with its respective values. Variable frequency was modelled using an *n-th* order polynomial. We empirically estimated an interval <2; 10> as n. This range of values proved to have stable results in the final heatmap. For polynomials of order $n > 10$ there was too much variability in the data and Lomb-Scargle algorithm did not produce a single dominant frequency. We also dealt with the fact that polynomials of order higher than 3 needed to have the noise level appropriately reduced.

Simulated time was based on the duration of the real observation. The constant frequency was in an interval from Tab. 1. The resulting periodogram and heatmap are on the panels Fig. 4(a)(b). The standard deviation for white noise simulation was generated from range in Tab. 1 and the corresponding products are on panels Fig. 4(c)(d). For the variable period we used polynomial regression. First, we generated points within Gauss distribution around a constant frequency. Next, we generated a polynomial function of *n-th* order and fitted it to the synthetic time series (Fig. 3(a)). We needed to cut out the generated polynomial (Fig. 3(b)). If the order of the polynomial is higher than 3, (1) produces oscillations with very high amplitude in the beginning and at the end of the simulated light curve. The values from the polynomial fit were used as frequency f in (1) to simulate variability in our light curve. The periodogram from the variable synthetic light curve together with its heatmap is in Fig. 4(e)(f). From each category we generated 1000 synthetic light curves which will be used in the CNNs training process. The main goal is to correctly classify small variabilities in each heatmap.

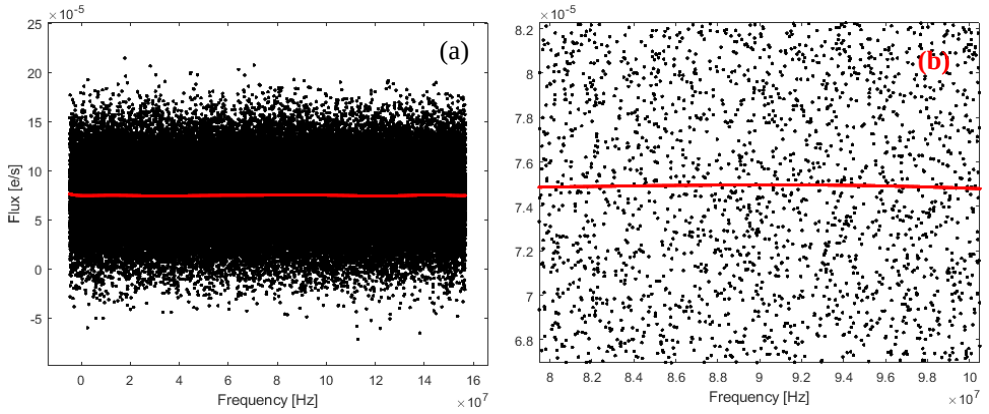

Fig. 3 – Generated frequency around a constant ($7.45 \cdot 10^{-5}$) (a, left); zoomed variable frequency (red line) used in (1) (b, right). Source: own research

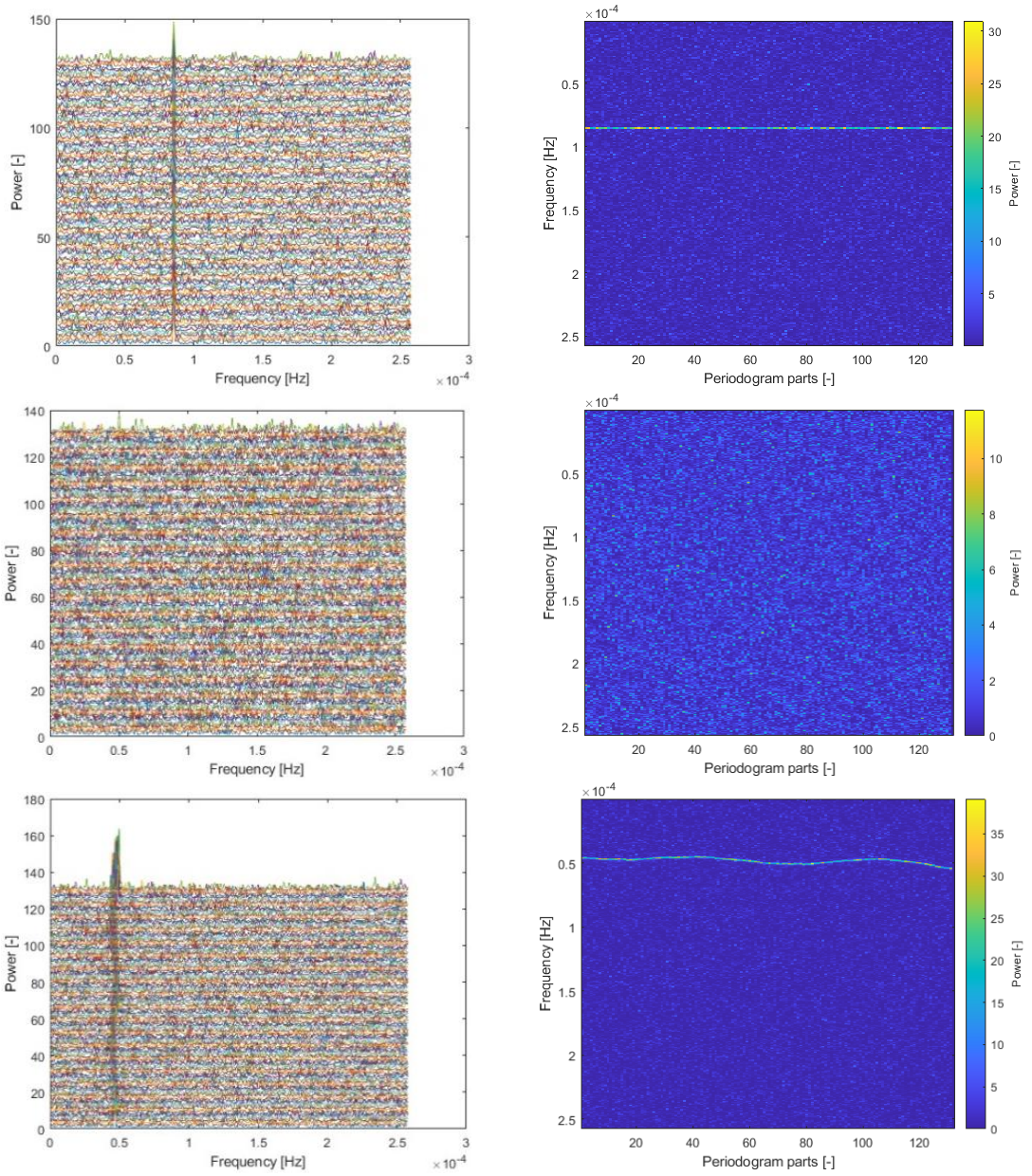

Fig. 4 – Simulated periodograms (left column) with corresponding heatmap (right column). Source: own research

3.3 CNN, training

In our work we want to test the feasibility of a CNN and its image classification capabilities. All work has been done in Matlab. We used a pretrained CNN called Xception. This is a 71-layer deep, feedforward network trained to classify 1000 different objects e.g., cat, pencil, car. The main reason to use a pretrained network was the fact that the architecture was already created, and the relative prediction time vs network accuracy ratio is lower meaning that the accuracy is higher with a lower prediction time.

We will be using supervised learning since we need to tell the algorithm which heatmap belongs to which category rather than letting the algorithm do the work. There are three training algorithms to choose from in Matlab. Based on our tests we chose the stochastic gradient descent with momentum (SGDM) algorithm. The momentum added to gradient descent helps to find the minimum of the cost function more easily with smaller steps so the algorithm will not overshoot the minimum. We used ReLU functions to minimize vanishing or exploding gradients with a softmax layer as an output unit activation function defined as:

$$P(c_r|x,\theta) = \frac{P(x,\theta|c_r)P(c_r)}{\sum_{j=1}^{k} P(x,\theta|c_j)P(c_j)} \tag{2}$$

To use Xception to classify our data we replaced the first, last and second last layers. We divided our training set so that 70% of it is used in the training process and 30% is used in the validation (cross-validation) during the training. Next, we empirically chose our training parameters. Together we had to train the network 3 times to obtain plausible results of variability detection. The training options along with the best parameters are in Tab. 2.

Tab. 2 – Training parameters of the CNN. Source: own research

sgdm	Learning rate	Validation frequency	Number of epochs	Minibatch size
1st training	$3e^{-4}$	50	7	10
2nd training	$3e^{-4}$	50	7	15
3rd training	$3e^{-4}$	50	20	5

For testing purposes, we used 1000 simulated samples, different from the ones used in training process, and statistically evaluated the network performance. We discovered that changing the number of epochs had the biggest impact on the network performance.

4 RESULTS

First, we tested the network with empirically chosen values of learning rate, validation frequency, number of epochs and minibatch size. Our statistical tests consisted of testing the network on 1000 heatmaps from each category and we evaluated the number of correctly classified samples. Next, we classified a heatmap from a real observation. The CNN trained with the parameters from the second row of Tab. 2 had a 98.37% training accuracy. The accuracy of classifying samples of simulated white noise was 99.2%, accuracy of classifying constant period samples 89.9% and variable period samples 97.8%. The averaged classification accuracy of the samples from all 3 categories in the first training was 95.63%. The accuracy of classifying the variability in real observation was only 14.71% and the rest was identified as a constant frequency with an 85.05% probability.

In the next training process, we changed the number of samples in minibatch size. We believe that the number of samples, simultaneously going through the network in the training process, can have an impact on the accuracy of the network. The training accuracy was 99.93%. As expected, this change increased the accuracy of predicting the correct category therefore the

accuracy of detection of variability in our real data sample increased to 20.93%. Most of the prediction was still in the constant frequency category. In the testing process, the samples of synthetic white noise were classified with a 99.8% accuracy, constant samples with a 99.5% accuracy and samples of variable frequency with a 98.6% accuracy. The average testing accuracy was 99.3%.

Increasing the minibatch size changed the prediction accuracy in a good way. But a further increase of this parameter led to a decline in the network accuracy. We also changed the number of training epochs. The training accuracy of the network was 100%. The network identified our real heatmap with a 99.64% probability as variable. The samples of white noise had a prediction accuracy of 98.1%, constant frequency 99.7% and variable frequency 99.5%. The resulting accuracy of the testing dataset was 99.1%, which is worse by 0.2% than in the network with parameters from 2nd training, however we will use this network for further work since the prediction accuracy of real data was very pleasing. The results from testing are summarized in Tab. 3 – Tab.5.

Tab. 3 – Testing of Xception from 1st training. Source: own research

1st training	Prediction of variability in data [%]					Number of predictions of other category [-]			
	<60	60-70	70-80	80-90	90-100	White noise	Constant period	Variable period	
White noise	0	1	3	4	992	0	0	0	
Constant period	8	18	18	27	899	9	0	21	
Variable period	3	3	4	7	978	5	0	0	
Training accuracy	98.37								[%]
Testing accuracy	95.63								
Real data	White noise prediction	0.24							[%]
	Constant period prediction	85.05							
	Variable period prediction	14.71							

Tab. 4 – Testing of Xception from 2nd training. Source: own research

2nd training	Prediction of variability in data [%]					Number of predictions of other category [-]			
	<60	60-70	70-80	80-90	90-100	White noise	Constant period	Variable period	
White noise	0	0	0	2	998	0	0	0	
Constant period	0	0	1	2	995	2	0	0	
Variable period	1	0	2	6	986	4	1	0	
Training accuracy	99.93								[%]
Testing accuracy	99.30								
Real data	White noise prediction	0.12							[%]
	Constant period prediction	78.95							
	Variable period prediction	20.93							

Tab. 5 – Testing of Xception from 3rd training. Source: own research

3rd training	Prediction of variability in data [%]					Number of predictions of other category [-]		
	<60	60-70	70-80	80-90	90-100	White noise	Constant period	Variable period
White noise	1	1	1	9	981	0	7	0
Constant period	0	1	0	2	997	0	0	0
Variable period	1	0	0	1	995	3	0	0
Training accuracy	100							[%]
Testing accuracy	99.10							[%]
Real data	White noise prediction	0.00						[%]
	Constant period prediction	0.36						
	Variable period prediction	99.64						

5 DISCUSSION

The problem of small variability detection does not only apply in period analysis. We used knowledge transfer for a similar signal problem. We studied the case of MV Lyr, a nova-like system depicting flickering at $f \simeq 1$ mHz. The object was also observed using Kepler telescope but with a short cadence 59 s. The light curve (Fig. 5(a)) was 272 days long and showed a linear trend. We cannot see any quasi-periodicity in the data, but we do know that the phenomenon is present in the data. This is a perfect sample for a machine learning approach to detect the variability. We used the same procedure as in the main part of this paper. We created Lomb-Scargle periodograms from the light curve (Fig. 5(b)). The periodograms had a log-log scale based on the fact which Dobrotka et al. (2020) mentioned in his work. The main reason was the detection of quasi-periodic oscillations. There is a steep decline to higher frequencies at around $f \simeq 1$ mHz meaning the presence of a quasi-periodic phenomenon. This is the point where we created a heatmap of our KIC 008751494 object. In this case we need to construct a power spectral density (PSD) to see the variability more clearly. We used binning with 0.05 bin length to average the 10-day periodograms (Fig. 5(c)). We can clearly see Lorentz profiles at $log(f) \simeq -3$, $log(f) \simeq -3.6$. The dominant frequencies do not produce a single peak but rather a slope meaning the frequencies are not constant and manifest in an interval. As a next step we fitted the PSD with a Lorentz model consisting of three Lorentz components. The parameters from the fitting procedure were used as an input to simulations of the observed data. We used Timmer & Koenig (1995) method for simulation, meaning we first created Fourier coefficients for the synthetic light curve defined as:

$$Y = G(\mu, \sigma, n) \cdot \sqrt{\frac{1}{2} S(\omega)} \tag{3}$$

G being random values drawn from Gauss distribution with a mean μ, standard deviation σ and the number n of values. S depicts the model used in the fitting process of our real data. We generated real and imaginary parts using (3) and then applied inverse Fourier transform to get values of flux. The resulting flux was then normalized to match the standard deviation and mean value of the real data. The following procedure is the same as with real data. From the periodogram simulations we created heatmaps (Fig. 5(d)), PSD and we want to also test the raw PSD data in the form of numerical time series. We will be searching for variable period in the

form of a Lorentz profile. For the heatmap classification we will use supervised learning with feedforward deep neural networks. We would like to modify the random forest method called isolated forest to detect “anomalies” in PSD using unsupervised learning. The anomalies will be the Lorentz profiles. The third form of simulations, time series, will use a support vector machine algorithm with a nonlinear kernel. The main goal of the kernel will be to extract the characteristic features (e.g., steep rise and fall of power in numeric data) using semi supervised learning.

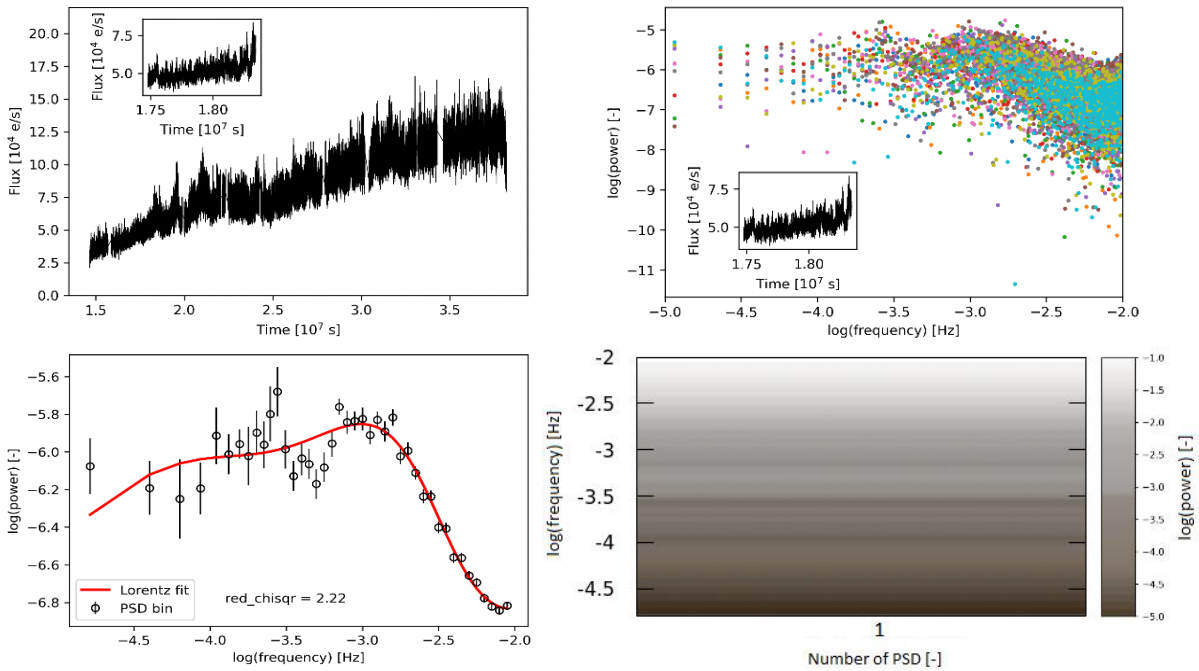

Fig. 5 – Observed light curve with its products (periodogram, PSD) and a simulated heatmap. Source: own research

6 CONCLUSION

We studied the case of a nova-like system KIC 008751494 observed with the Kepler space telescope. We were looking for variabilities in its light curve and developed a machine learning algorithm to prove the feasibility of it in the field of astronomy. First, we needed to confirm the existence of this phenomenon. We divided the light curve into 10-day segments and used the Lomb-Scargle algorithm to compute a periodogram from each part. We found a variable signal at $f \simeq 9$ mHz with a noise component at $f \simeq 18.5$ mHz. We grouped the periodograms into a heatmap. Our main goal was to research the feasibility of a CNN in detection of small, subtle changes in image-based data. We used the scientific computing environment of Matlab and a pretrained CNN Xception. We trained the network to find features in our data. We concluded that increasing the number of epochs to 20 and reducing the minibatch size to 5 increased the CNNs prediction accuracy. We managed to predict variability in real data with a 99.64% accuracy, meaning CNN can provide a good tool to detect variabilities in astronomical data. To achieve a similar accuracy in identifying variability in other astronomical phenomena e.g., Lorentz profiles, one must change the synaptic weights of convolutional layers. We can compute them manually which is very time consuming. Another solution is to add a new category called variable-constant frequency. This category will contain variable period on a chosen range (max. 75% of the period length) and a constant period on the remaining range. If the results would be insufficient a larger training dataset will be needed. Our idea of this dataset is to create more diversity in the variable frequency and variable-constant frequency category

i.e., their respective amplitudes. Amplitudes less than $0.1 \cdot 10^{-4}$ are sparse in the current training data. The amount of data of the variable-constant frequency category must also have an equal ratio i.e., 333 items would have variable amplitude in the first 5-30% of the periodogram's whole length, 333 items with variable amplitude in 31-50% and 333 items with variability in 51-75% of the periodogram. As we observed in our researched object, KIC 008751494, the amount of variability and the ranging of it is too low. The accuracy of a CNN trained with data as mentioned is our future work where we will confirm or refute our hypotheses.

In our future work we will try several different machine learning methods together with transferring knowledge to a similar case of a nova-like system MV Lyr. This system shows quasi-periodic oscillations which can be seen in its PSD as a slope (Lorentz profile), the heatmap is more obscured compared to our main researched object. We will also use numerical data to train selected machine learning models. We will create a support vector machine with a nonlinear kernel based on a semi-supervised learning approach. We will also focus on creating an isolated forest to detect anomalies i.e., the Lorentz profiles, or variabilities in supernova outbursts. Similar approach used Ahrens et al. (2019), whereas his prediction accuracy was 85%. We are optimistic that machine learning has a bright future in astronomy, not only in data processing but also in outer space missions.

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THE EFFECT OF CRYOGENIC TREATMENT ON WEAR PERFORMANCE OF VANADIS 6 STEEL

Venu Yarasu, Lukáš Rausa, Jurči Peter, Horník Jakub

Abstract

In this study, wear analysis was performed on the Vanadis 6 PM tool steel, and the results were analysed using experimental and statistical methods. The experimental steel was subjected to different cryogenic treatments along with the tempering treatments. A Pin-on-disk configuration was used to perform the wear tests as per ASTM E384-17. 100Cr6 steel balls were used as counter-body material, and Taguchi L18 orthogonal array was used to conduct the wear experiments. Analysis of variance analysis was applied to the final results. The optimal hardness was attained by sub-zero treatment at -140°C after tempering at 170°C. Statistical techniques observed that a tempering treatment at 170°C, sub-zero treatment at -196°C, sliding velocity of 6.4 cm/s, and 5 N normal load gives the optimum setting for mean friction coefficient, while a tempering treatment at 170°C, sub-zero treatment at -140°C, sliding velocity of 6.4 cm/s, and 1 N normal load gives the optimum setting for minimum wear rate and counter material transfer.

Keywords: *Cold-work tool steel, Cryogenic treatment, Tempering, Wear, Taguchi OA*

1 INTRODUCTION

Vanadis 6 tool steel is a special Cr-V ledeburitic steel with superior wear resistance properties. This class of steels contains chromium in the range of 6-12 wt.%, and high amount of vanadium more than 5 wt.%. Chromium forms less stable carbides, which dissolve in austenite during heat treatment, increasing the concentration of alloying elements in solid solution and resulting in excellent hardenability. MC-carbides formed by vanadium, on the other hand, are more stable and do not dissolve during austenitization. Mc-carbides are extremely hard and improve the steels' resistance to abrasive wear. Cr-V ledeburitic steels with a higher vanadium content are only produced through the rapid solidification route in powder metallurgy. This technology removes physical and mechanical property segregation and anisotropy, which are typical problems with conventional methods (Bílek et al., 2011; Jurči, 2011).

2 THEORETICAL BACKGROUND

Conventional heat treatment (CHT) of Cr-V ledeburitic steels includes the following steps: vacuum austenitizing, keeping at the desired temperature, nitrogen gas quenching, and two or three tempering cycles. Due to the saturation of austenite with carbon and alloying elements, both the start and finish temperatures of martensite are lowered. As a result, CHT alone is insufficient to transform a significant amount of austenite to martensite. In particular, sub-zero treatment (SZT) has proven to be more beneficial to convert retained austenite (γR) into martensite over CHT for Cr, and Cr-V ledeburitic steels (Jurči, 2011; Jurči et al., 2015a). For instance, many authors reported complete elimination of γR amount, when Cr and Cr-V ledeburitic steels are subjected to cryogenic treatments (Das et al., 2010a; Das & Ray, 2012; Das et al., 2009a; Das et al., 2009b). On the other hand, SZTs not only eliminates γR, but also refines the martensite (Tyshchenko et al., 2010; Jurči et al., 2015a; Villa et al., 2014), forms "extra" small globular carbides (SGCs) (Jurči et al., 2015a; Jurči et al., 2015b) and modifies the precipitation of nano-sized precipitates (Das et al., 2009b; Jurči et al., 2015b). It was recently

identified (Jurči et al., 2015b) that the minimum γR value in Vanadis 6 steel is achieved following a 17-hour SZT.

SZTs can increase the wear resistance of tool steels, but the degree of improvement varies by material. For example, the wear resistance of AISI D2 steel showed an increase of 316 and 817 %, and for H13 (hot-work tool steel) the increment is 164 and 209% when processed at -79 and -196°C, respectively for both the material (Gill et al., 2010). On the other hand, there was only 50–70% improvement in wear performance of AISI D3 steel was documented, after SZT at -195°C for 36 h (Akhbarizadeh et al., 2013). It was found that the wear performance of AISI D6 steel was improved by just 5–30% when processed at -180°C for 24 h (Thornton et al., 2013). On the other hand, according to recent studies (Jurči et al., 2019) the Cr-V ledeburitic steels have shown significant improvement in hardness from 197 to 137 HV 10 when subjected to SZT at -140°C, over CHT. Significant research has been conducted to determine the benefits of SZT on mechanical properties. However, no comparative analysis of Vanadis 6 material is available at this time.

The aim of this work is to investigate the effect of various sub-zero temperatures on the wear properties of Vanadis 6 (Cr-V) ledeburitic tool steel. The purpose of this work is to optimize sub-zero temperature in order to achieve the lowest friction coefficient, wear rate, and counterpart material transfer.

3 METHODOLOGY

3.1 Material and processing

Vanadis 6, a Cr-V ledeburitic tool steel produced by powder metallurgy, was used in this study. Table 1 shows the nominal chemical composition of the material.

Tab. 1 – Nominal Composition of Cr-V Ledeburitic Tool Steel. Source: own research

C	Si	Mn	Cr	Mo	V	Fe
2.1	1.0	0.4	6.8	1.5	5.4	Bal

The following parameters were used in the heat-treatment: austenitizing at 1050°C for 30 minutes, quenching in nitrogen gas at 5 bar pressure, sub-zero treatments at -75, -140, and -196°C for 17 hours, and double tempering at 170, and 530°C for 2 hours each. After tempering the samples were air-cooled.

3.2 Hardness testing

To determine the hardness of the various cryo-treated specimens, the Vickers hardness tester was used. The indentation process was performed with a load of 10 kgf (98 N) and a minimum of five readings were obtained to determine the average hardness of each individual sample.

3.3 Wear testing

The wear tests were conducted in a pin-on-disk configuration, using commercially available 100Cr6 bearing steel balls with a diameter of 6 mm as a counterpart with a hardness of 735 HV 10. The tests are conducted using the following test parameters: 1, 5, and 10 N standard loads, 6.4, 12.8, and 18.85 cm/s sliding velocities, and a total sliding distance of 100 meters. All the tests were performed at room temperature.

The wear volume loss of the samples (V_l) was calculated according to Equation 1 (G02 Committee, n.d.).

$$V_l = 2\,\pi R[\left[\frac{r2}{\sin\left(\frac{d}{2r}\right)}\right] - \frac{d}{4}\sqrt{4r^2 - d^2}] \quad (1)$$

Where R denotes the radius of the wear track, d denotes the mean width of the wear track, and r denotes the radius of the counterpart ball. The wear rate (W_R) was then measured using Archard's classical wear law, which can be expressed as Equation 2 (Das et al., 2010b).

$$W_R = K * \frac{F_N}{HV} \quad (2)$$

Where W_R is wear rate (in mm^3/m), K is the wear coefficient, F_N is the applied load (in newtons), and HV denotes the hardness of the softer of the materials in contact.

3.4 Design of experiments

When the number of factors and levels increases, the number of experiments will increase as well. As a result, the design of experiments approach was used for conducting the experiments and based on control factors and levels, the Taguchi L18 orthogonal array lay out was used to run the experiments. Taguchi design is a prominent method for optimizing process parameters with a minimal number of experiments. Signal to noise (S/N) ratios are employed in the Taguchi method to evaluate the process performance. Those signal to noise ratios indicates product quality, with a greater S/N ratio indicating higher quality. As illustrated in Equations 3-5, there are three types of S/N ratios in the Taguchi method: lower is better (S/N_L), higher is better (S/N_H), and nominal is better (S/N_N) (Achuthamenon Sylajakumari et al., 2018; Roy, 2010).

$$\frac{S}{N_L} = -10 * log_{10}[\left(\frac{1}{n}\right)\sum(y^2)] \quad (3)$$

$$\frac{S}{N_H} = -10 * log_{10}\,[\left(\frac{1}{n}\right)\sum\left(\frac{1}{y^2}\right)] \quad (4)$$

$$\frac{S}{N_N} = 10 * log_{10}\left[\left(\frac{y_A}{S_y^2}\right)\right] \quad (5)$$

Where n is the number of observations; y is the observed value; y_A is the average of observed value; and S_y^2 is the variance of y.

To summarise, the Taguchi experimental design involves the following steps: (i) identify the factors and their levels, (ii) selection of orthogonal array, (iii) conducting experiments based on the orthogonal array, (iv) analysing the results using signal to noise rations (S/N ratios), (v) conduct ANOVA test to identify the statistical significance of the factors, and (vi) confirmation tests. Further, Table 2 shows the mixed level process parameters used in the analysis.

Tab. 2 – Process Parameters and Levels. Source: own research

Process Parameter	**Level 1**	**Level 2**	**Level 3**
A: Tempering Temperature (TT, in °C)	170	530	-
B: Sub-Zero Temperature (SZT, in °C)	-196	-140	-75
C: Sliding Velocity (Sv, in cm/s)	6.4	12.8	18.85
D: Load (L, in Newtons)	1	5	10

4 RESULTS

4.1 Hardness

Figure 1 shows the calculated mean Vickers hardness values of the experimental material at different sub-zero, and tempering temperatures. SZT at -140°C, combined with a tempering treatment at 170°C, produces the highest hardness. In addition, when the tempering temperature rises, the material's hardness decreases. It's worth noting that the current findings are in perfect agreement with the other researchers (Jurči et al., 2019).

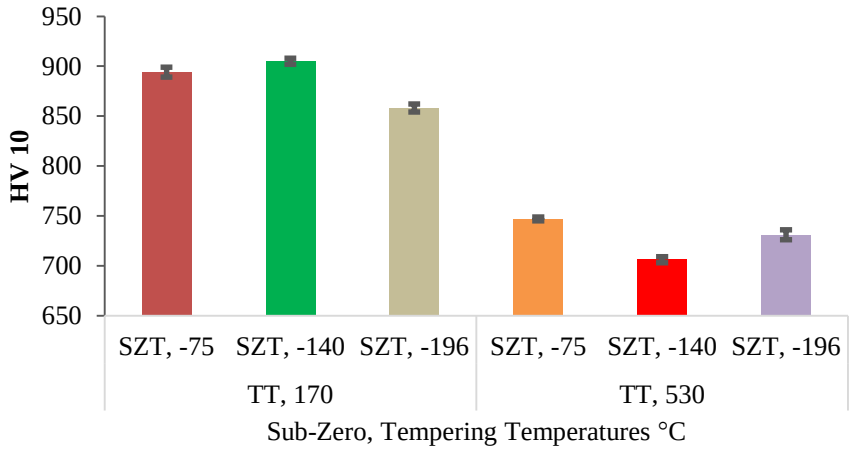

Fig. 1 – Average Hardness of Different Treatments, Vanadis 6. Source: own research

4.2 Wear

Table 3 presents the experimental results of wear tests i.e. coefficient of friction, wear rate in $mm^3/m \times 10^7$, and counterpart material transfer in %. The adhered counterpart material was calculated as the percentage of area covered by the adhered counterpart material inside the wear track. These calculations were performed on twenty random SEM images of the wear tracks. Further the mean values were calculated and used in the analysis.

Tab. 3 – Experimental Results, Coefficient of Friction (COF), Wear Rate (W_R), Counterpart Material Transfer (CMT). Source: own research

Run	TT	SZT	Sv	L	COF	W_R	CMT
1	170	−75	6.4	1	0.666	11.2	7.0
2	170	−75	12.8	5	0.597	20.5	17.0
3	170	−75	18.85	10	0.707	31.1	13.9
4	170	−140	6.4	1	0.702	10.1	7.1
5	170	−140	12.8	5	0.623	26.4	19.2
6	170	−140	18.85	10	0.715	31.0	19.1
7	170	−196	6.4	5	0.565	17.6	27.7
8	170	−196	12.8	10	0.619	23.3	29.4
9	170	−196	18.85	1	0.726	4.7	31.4
10	530	−75	6.4	10	0.571	39.6	22.1
11	530	−75	12.8	1	0.748	7.7	23.3
12	530	−75	18.85	5	0.737	24.6	19.9
13	530	−140	6.4	5	0.608	32.0	21.0
14	530	−140	12.8	10	0.652	33.2	13.9
15	530	−140	18.85	1	0.842	10.8	13.3
16	530	−196	6.4	10	0.601	51.4	13.9
17	530	−196	12.8	1	0.783	9.0	24.7
18	530	−196	18.85	5	0.717	20.9	18.9

5 DISCUSSION

5.1 Analysis of experiments

The experiments were performed based on the Taguchi L18 orthogonal array, and the corresponding results i.e. coefficient of friction (COF), wear rate (WR in mm^3/m), and counterpart material transfer (CMT in %) are presented in Table 4.

Tab. 4 – Taguchi Results, Coefficient of Friction (COF), Wear Rate (W_R), Counterpart Material Transfer (CMT).

Source: own research

Run	TT	SZT	Sv	L	COF	S/N	W_R	CMT	S/N
1	170	−75	6.4	1	0.666	3.53052	11.2	7.0	-1.00487
2	170	−75	12.8	5	0.597	4.48051	20.5	17.0	-4.85326
3	170	−75	18.85	10	0.707	3.01161	31.1	13.9	-5.13701
4	170	−140	6.4	1	0.702	3.07326	10.1	7.1	-0.91777
5	170	−140	12.8	5	0.623	4.11024	26.4	19.2	-5.86594
6	170	−140	18.85	10	0.715	2.91388	31.0	19.1	-6.26801
7	170	−196	6.4	5	0.565	4.95903	17.6	27.7	-5.88218
8	170	−196	12.8	10	0.619	4.16619	23.3	29.4	-6.84190
9	170	−196	18.85	1	0.726	2.78127	4.7	31.4	-3.52183
10	530	−75	6.4	10	0.571	4.86728	39.6	22.1	-7.65376
11	530	−75	12.8	1	0.748	2.52197	7.7	23.3	-3.27672
12	530	−75	18.85	5	0.737	2.65065	24.6	19.9	-6.14160
13	530	−140	6.4	5	0.608	4.32193	32.0	21.0	-5.04167
14	530	−140	12.8	10	0.652	3.71505	33.2	13.9	-6.78497
15	530	−140	18.85	1	0.842	1.49376	10.8	13.3	-2.90353
16	530	−196	6.4	10	0.601	4.42251	51.4	13.9	-7.54427
17	530	−196	12.8	1	0.783	2.12476	9.0	24.7	-2.59516
18	530	−196	18.85	5	0.717	2.88962	20.9	18.9	-6.03918

The Taguchi method uses signal to noise ratios to analyse the experimental results. The aim of this analysis is to minimize the response variables, hence in the S/N analysis for COF, the smaller the better characteristic was chosen, while in the case of W_R and CMT, the larger the better characteristic was chosen. The experimental design was developed and evaluated using the MINITAB 19 software. In the analysis, the higher the S/N ratio, the better the quality. So, the best process settings are obtained by taking the highest S/N value. Figure 2 and 3 show graphically the effects of process parameters on COF, and W_R, CMT. From Figure 2, the optimum condition for the minimum COF is found to be $A_1B_1C_1D_2$. Similarly, From Figure 3, the optimum condition for minimum wear rate and counter material transfer is found to be $A_1B_2C_1D_1$.

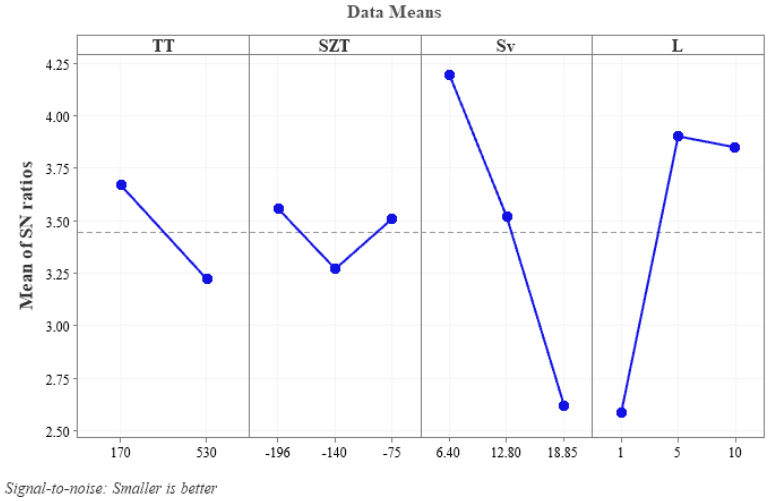

Fig. 2 – Main Effects Plot for S/N Ratios, COF. Source: own research

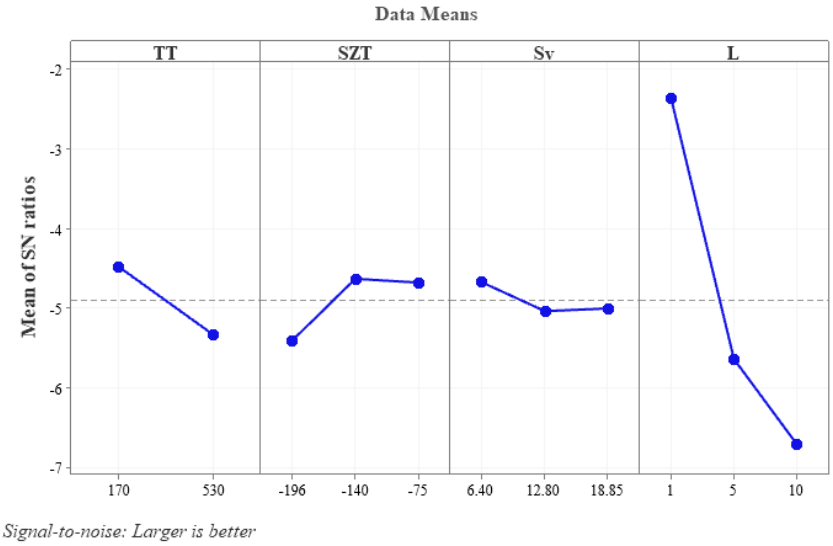

Fig. 3 – Main Effects Plot for S/N Ratios, W_R and CMT. Source: own research

5.2 ANOVA and factor contributions

The Taguchi approach does not allow for the evaluation of each factor's effect on the response variables. As a result, ANOVA is aimed at determining the significance and contribution of each variable (Roy, 2010). The signal to noise ratios were analysed using the ANOVA test to determine the importance of the input variables. The ANOVA results for coefficient of friction are shown in Table 5, and the test results for wear rate and counterpart material transition are shown in Table 6.

The P-value indicates the statistical significance of the variables in an ANOVA test. If the P-value is less than 0.05, the factor is statistically significant; if it is greater than 0.05, it is not. From Table 5, for COF, factor A (tempering temperature) is having statistical significance with P-value (0.023), factor B (sub-zero temperature) is having no significance with P-value (0.363), factor C (sliding velocity) and factor D (load) are having strong statistical significance with P-value (0.000). From Table 6, for WR and CMT, factor A (tempering temperature) is having statistical significance with P-value (0.04), and factor D (load) is having strong statistical significance with P-value (0.000). Whereas, factor B (sub-zero temperature) and factor C (sliding velocity) are not having statistical significance.

Tab. 5 – ANOVA Test Results for COF. Source: own research

Source	DF	Seq SS	Adj SS	Adj MS	F	P	% C
A	1	0.897	0.897	0.897	7.15	0.023	5
B	2	0.282	0.282	0.141	1.12	0.363	2
C	2	7.465	7.465	3.732	29.72	0.000	45
D	2	6.645	6.645	3.323	26.46	0.000	40
RE	10	1.256	1.256	0.126			
Total	17	16.545					

DF: degrees of freedom, Seq SS: sequential sum of squares, Adj SS: adjusted sum of squares, Adj MS: adjusted mean squares, %C: contribution

Tab. 6 – ANOVA Test Results for W_R, CMT. Source: own research

Source	DF	Seq SS	Adj SS	Adj MS	F	P	% C
A	1	3.2837	3.2837	3.2837	5.28	0.04	4
B	2	2.2567	2.2567	1.1284	1.82	0.21	3
C	2	0.4797	0.4797	0.2398	0.39	0.69	1
D	2	61.2154	61.2154	30.6077	49.26	0.00	83
RE	10	6.2134	6.2134	0.6213			
Total	17	73.4489					

DF: degrees of freedom, Seq SS: sequential sum of squares, Adj SS: adjusted sum of squares, Adj MS: adjusted mean squares, %C: contribution

5.3 Confirmation

The confirmation test is the final step in the experiment design process since it verifies the model's accuracy by measuring the errors between the expected and actual values. The results of validation tests for COF, WR, and CMT are shown in Tables 7 and 8. The confirmatory tests had error values of less than 10%, showing that the model was of higher quality.

Tab. 7 – Results of Confirmation Test, COF. Source: own research

Level	Predicted Value	Experimental Value	% Error
$A_1B_1C_1D_2$	0.556	0.565	2

Tab. 8 – Results of Confirmation Test, W_R, CMT. Source: own research

Level	Predicted Value	Experimental Value	% Error
$A_1B_2C_1D_1$	0.848	0.900	6

6 CONCLUSION

The effect of different sub-zero treatments (-75, -140, or -196°C) on the wear efficiency of Vanadis 6 steel was investigated for a 17-hour period and followed by subsequent tempering. According to the analysis, the main findings are as follows: (1) SZT at -140°C followed by the tempering treatment at 170°C yields the maximum hardness. (2) SZT at -196°C is the optimal temperature for achieving the lowest coefficient of friction when other conditions such as tempering temperature of 170°C, sliding velocity of 6.4 cm/s, and load of 5 N are used. (3) For the lowest wear rate and counterpart material transfer, SZT -140°C is the optimal setting, along with tempering at 170°C, sliding velocity of 6.4 cm/s, and load of 1 N. (4) The error values for both optimal conditions are less than 10%, indicating that the model is highly accurate.

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EARLY STEPS OF DESIGN AND OPTIMIZATION MODEL OF DISTINCTIVELY HEAVY AND LONG UNIT LOADS AUTOMATED STORAGE AND RETRIEVAL SYSTEMS

Anja Žagar, Jakob Marolt, Tone Lerher

Abstract

Effective planning and optimisation of a storage unit is crucial for development companies, because this is the only way to achieve a high-tech system with minimal storage costs. This paper presents a framework for planning a design and optimisation model of an automated storage and retrieval system of extremely heavy and long unit loads with the use of the automated storage and retrieval machine (SR machine), which lays the foundation for a future research work in a doctoral dissertation. The motivation to define such a problem originates in a company that faces challenges of manual and mechanical storage as well as retrieval of steel profiles in bundles. There is a lack of research in the area of design model of storage systems for extremely heavy and long loads. In order to fill the established gap, we plan a model that refers to the upgrade from the floor storage technology for extremely heavy and long loads to the automated storage and retrieval system with the use of the storage and retrieval machine (SR machine). When designing this model, we derive from the required throughput capacity of a storage unit (the number of cassettes of steel profiles per time unit), which depends on the form of the storage rack, kinematic characteristics of the SR machine and adequate storage strategy. Moreover, we consider the criterion of electricity consumption since electricity is needed for the operation and management of the material handling equipment. The optimization of the designed model is achieved by minimising electricity consumption and consequently CO_2 emissions while considering the electricity regeneration. Furthermore, in the existing model, we propose a new storage strategy that considers the material throughput and storage location, and establish its impact on electricity consumption of the SR machine. In line with the global trends of automated storage systems, we consider the economic and environmental aspect while designing and optimising the storage model for extremely heavy and long loads, and combine throughput capacity/energy consumption/storage strategy.

Keywords: *automated storage and retrieval system, optimization, model design, heavy and long unit loads, energy regeneration, storage strategy*

1 INTRODUCTION

A storage unit in a manufacturing company relating to storage of raw materials, semi-finished goods and final products is one of the most important areas of intralogistics from the industrial and economic perspective.

Storage costs represent 20 to 30% of the entire logistics expenses (Rushton et al., 2010). Logistics costs are the highest in the floor storage technology, where transport unit loads (TUL) are stored on the floor. Logistics manipulations are carried out manually and mechanically, which requires the presence of a storer acting as the operator of a forklift or an overhead crane. Our motivation to define the aforementioned problem originates in the company that we collaborated with from 2017 to 2020 on an applicative research project ARRS (project number: L5-8237), which is based on an increase of efficiency of the intralogistics system in steel industry, as the company was facing problems of manual and mechanical storage and retrieval of steel profiles in bundles (Figure 1).

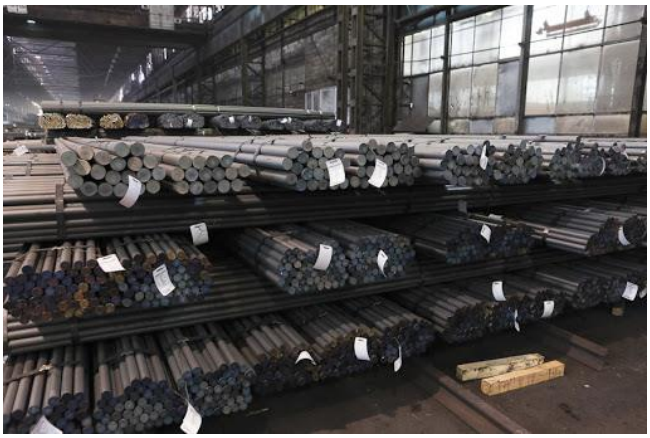

Fig. 1 – Steel profiles in bundles. Source: own research

Steel profile bundles are primarily stored on an available floor disposal unit. Storage is conducted by following the concept that steel profile bundles are stacked one on top of another, whereas cargo manipulation is ensured by the overhead crane. In case of retrieval of a selected steel profile bundle it is necessary to shift goods to the closest available disposal unit (Figure 2).

Fig. 2 – The bridging problem of steel profiles. Source: Hliš (2019)

The TUL floor storage costs can be considerably reduced by using the automation of material handling equipment. The automation of storage processes can be achieved by implementing the automated storage and retrieval systems with the use of the storage and retrieval machine (SR machine) as the main transport device.

Depending on the type of storage material, automated storage and retrieval systems are divided into systems of automated storage and retrieval of cargo with an SR machine (crane-based mini-load AS/RS), systems of automated storage and retrieval of pallets with the SR machine (crane-based unit-load AS/RS) and storage and retrieval systems with autonomous or automated mobile vehicles (AVS/RS and SBS/RS).

Automated storage and retrieval systems of extremely heavy loads in cassettes with the SR machine are presented below. The most appropriate and well-known type of automated storage and retrieval system in practice for extremely heavy-weight and long-dimension loads is a storage unit that is based on transport of cassettes of steel profiles. This type of storage unit essentially consists of adequately dimensioned storage racks, an SR machine for extremely heavy loads, accumulating (roller) conveyors, input and output storage location as well as a computer system for managing and organising storage activities (Figure 3).

Fig. 3 – Automated storage and retrieval systems of extremely heavy loads in cassettes. Source: Fehr Lagerlogistik (n.d.)

High-tech system with minimum costs of storage operation can only be achieved through an adequate storage design. An important criterion in storage design is the ability to achieve the required throughput capacity of a storage unit (number of cassettes of steel profiles per time unit), which depends on the form of the storage rack, kinematic characteristics of the SR machine and adequate storage strategy. Furthermore, in order to ensure the storage sustainability condition, the injected electricity consumption for operating and managing the material handling equipment is growing relevance in storage design. The electricity consumption also depends on the form of storage racks, the use of energy efficient material handling equipment and the adequate storage strategy. In modern storage systems, the energy regeneration model is used in case of braking of an SR machine and moving downwards (descending) the hoisted carriage of the SR machine (Zajac, 2016; Meneghetti & Monti, 2012). Electricity consumption in transport is often linked with CO_2 emissions created as a by-product of electricity generation in thermal power plants. Our aim is to conduct responsible and sustainable activities in storage units, which is why we strive to minimise electricity consumption in transport by using energy regeneration, which has in turn an impact on lower CO_2 emissions. Designing an efficient automated storage and retrieval system can be achieved by optimising the decision variables in the objective function relating to electricity consumption and CO_2 emissions while achieving the required storage throughput capacity.

The research subject is the elaboration of a framework of a design and optimisation model of automated storage and retrieval system of extremely heavy loads with the use of the automated SR machine. In scientific literature overview, we observed a lack of research in the field of design and optimisation model development for storage systems of extremely heavy loads. The request for minimising the electricity consumption while considering energy regeneration and consequently minimising the CO_2 emissions while achieving the required storage throughput capacity will guide us through the process of designing and using the objective function with the method of the objective function optimisation by genetic algorithms.

2 LITERATURE REVIEW

We divided literature overview in two parts. The first part sums up the scientific work relating to storage systems of extremely heavy and large loads that are based on floor storage technology and manipulation of the overhead crane. The second part summarises the scientific work relating to automated pallet storage and retrieval systems that can be used for extremely heavy and large loads subject to adequate adjustments.

2.1 Floor storage technology for extremely heavy loads

The literature overview of scientific research work on storage systems of extremely heavy and large loads is not vast in quantity. One reason is that the majority of items is still stored on

pallets, followed by items stored in containers and the remainder is composed of other forms of transport unit loads, including those that are appropriate for storing extremely heavy and large loads (Rushton et al., 2010). Extremely heavy and large loads represent a major challenge for efficient storage as they require the adjustment of the transport and storage system (Nagasawa et al., 1975; Rushton et al., 2010). Yuan and Tang (2017) established that storage systems of extremely heavy and large loads are mainly used in steel industry, container terminals and other metalworking industries.

The first studies on problem solving in the field of floor storage technology for extremely heavy and large goods were focused on minimising the shifts of steel plates, coils and profiles in order to ensure smooth production and retrieval process (Tang et al., 2002; Tang et al., 2012). In addition to the studies related to the minimisation of shifts of steel profile bundles and coils, we also observed those that are based on operating the overhead crane (Zhao & Tang, 2010; Maschietto et al., 2016). Xie et al. (2014) combined the challenge of minimising the shifts of steel coils and optimising the management of several overhead cranes with the use of a mathematical model of linear programming and simulation. The researches on minimising the shifts of extremely heavy loads and managing the overhead crane encouraged the authors to study the increase of throughput capacity of a storage system (Zapfel & Wasner, 2006; Seidlova & Sourek, 2010; Yuan & Tang, 2017; Lei et al., 2018).

Our scientific literature overview of storage systems of extremely heavy and large loads revealed that this area is still actively evolving. In their scientific research papers, authors optimised the existing storage units that were based on TUL floor storage technique. They applied criteria that are important for optimising the storage systems. They developed mathematical and numerical models for problem-solving (minimising the number of shifts of steel profile bundles and coils in order to improve production and retrieval, introducing new strategies, achieving the maximum throughput capacity of a storage system, optimising the management of the overhead crane). In literature overview, we observed a lack of model that would relate to the upgrade from a TUL floor storage technology to an automated storage and retrieval system with the use of the SR machine.

2.2 Automated pallet storage and retrieval systems

Our literature overview did not reveal any studies on designing and optimising automated storage systems for extremely heavy and large loads, which is why we will summarise scientific papers related to the automated pallet storage and retrieval systems with the SR machine. In our scientific literature review, we will focus on automated pallet storage and retrieval systems with the SR machine intended for single-aisle and single-depth pallet storage. Moreover, we will consider the operating of the SR machine in single and dual command cycles. A study on the aforementioned storage systems will be conducted with the aim to present the existing analytical and numerical models, which are important for designing and optimization a storage system.

The first set of research relates to the proposed analytical and numerical models that are based on the improvement of storage throughput capacity while considering the SR machine travel (single and dual command cycles), storage shape (storage rack) as well as the impact of different storage strategies on the storage throughput capacity (Gudehus, 1973; Hausman et al., 1976; Bozer & White, 1984; Han et al., 1987; Houshyar & Chung, 1991; Randhawa & Shroff, 1995; Mansuri, 1997; Wen et al., 2001; Rao & Adil, 2015; Bortolini et al., 2015, Heßler, 2017).

Recently, authors shifted their studies from the field of single-depth TUL storage and the SR machine operation in a single picking aisle to multi-depth TUL storage (Lerher et al., 2010). Moreover, we discovered studies of the SR machine operation in multiple picking aisles

(Hwang & Ko, 1988) and transport of several TULs at a time (Keserla & Peters, 1994; Meller & Mungwattana, 1997). A recent trend (since 2000) has been for studies to swerve towards the remaining types of automated storage systems (storage systems of small loads that use the SR machine for cargo transport – mini-load AS/RS), followed by automated storages with automated vehicles transporting loads horizontally, whereas the cranes serve for lifting the load vertically (AVS/RS and SBS/RS).

The second set of research concerns the reduction of electricity consumption while considering the storage shape, the SR machine travel and the use of a suitable strategy for storage/retrieval (Zhou & Mao, 2010; Meneghetti & Monti, 2011; Bortolini et al., 2016; Rajković et al., 2017).

Within the context of electricity consumption research, the authors discovered the importance of energy regeneration in the SR machine travel and lowering (moving downwards) the hoisted carriage of the SR machine (Meneghetti & Monti, 2012; Jerman et al., 2017).

Following a thorough scientific literature overview, we established that authors developed analytical and numerical models in the field of (single-depth) single-aisle automated pallet storage and retrieval systems. The suggested models are based on the improvement of the storage throughput capacity while considering the SR machine travel (single and dual command cycles) and storage shape (storage rack) as well as the impact of different storage strategies on the storage throughput capacity. Recently, studies focused on reducing the electricity consumption while considering storage shape, the SR machine travel and the usage of a suitable strategy of storage/retrieval. Furthermore, the authors discovered the importance of energy regeneration in the SR machine travel and lowering (moving downwards) the hoisted carriage of the SR machine. In scientific literature overview, we have not observed any model on design of automated storage systems of extremely heavy loads that would be, in view of the required storage throughput capacity, based on (i) the optimisation of minimum power consumption, (ii) consideration of the SR machine kinematic parameters and (iii) impact of storage strategy and would in this way connect the throughput capacity/power consumption/CO_2 emissions.

3 METHODOLOGY

The methodology for establishing a framework to design and optimise a model of automated storage and retrieval system for extremely heavy and long unit loads with the use of the automated storage and retrieval machine (SR machine) is set out below. Figure 4 presents a flow chart that includes all relevant planning steps.

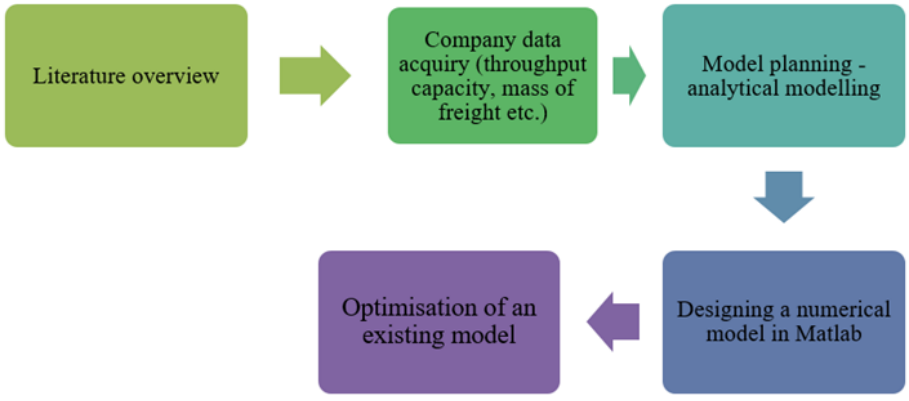

Fig. 4 – Flow chart of planning steps. Source: own research

We will study a vast amount of literature with the method of analysis of storage systems for extremely heavy and large loads with the overhead crane, the method of analysis of automated pallet storage and retrieval systems with the SR machine and the method of compiling the

existing studies of the aforementioned fields, and set the bases for further research. A company engaged in steel storage will provide us with real data on the required throughput capacity and mass of steel products that will serve us as a fixed input data for a designed model.

We will focus on designing a unit load AS/RS storage for extremely heavy and large loads that will consist of adequately dimensioned storage racks and aisles between which the SR machine will travel. A cassette will be the base storage transport unit. The implementation of the storage operation will be based on single and dual command cycles. The SR machine will travel horizontally and vertically at the same time, with non-constant speed, and its acceleration and deceleration will have to be considered.

The model design will begin with analytical modelling. Given the required throughput capacity, we will define the shape of the storage rack and kinematic characteristics of the SR machine by using analytical expressions.

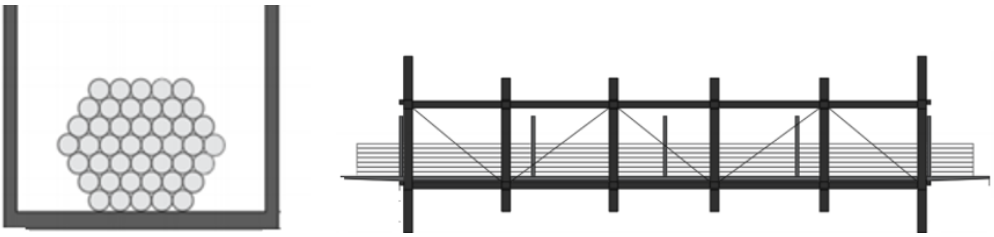

Fig. 5 – The main transport storage unit – cassette and storage rack. Source: Hliš (2019)

With the use of analytical expressions, we will also define the power of the SR machine propelling engines needed for acceleration, deceleration and constant speed. On the basis of manipulation time, path and power of the propelling engines, we will define analytical expressions to calculate the electricity consumption of the SR machine and energy regeneration in case of deceleration of the SR machine and lowering (moving downwards) its hoisted carriage.

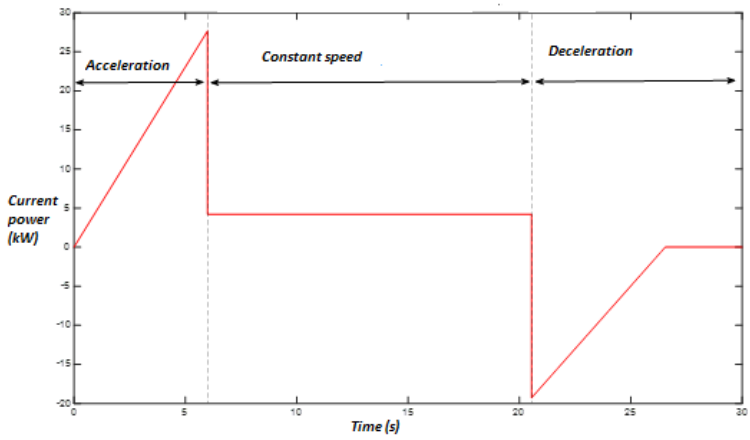

Fig. 6 – Engine power in acceleration, constant speed and deceleration of the SR machine. Source: own research

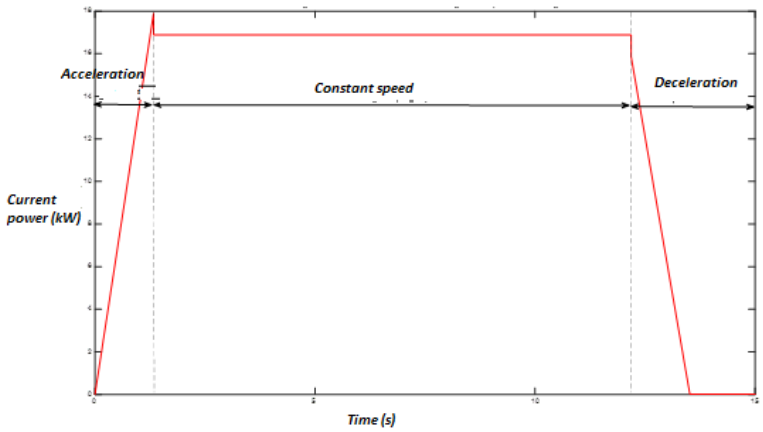

Fig. 7 – Engine power in acceleration, constant speed and deceleration when raising the hoisted carriage of the SR machine. Source: own research

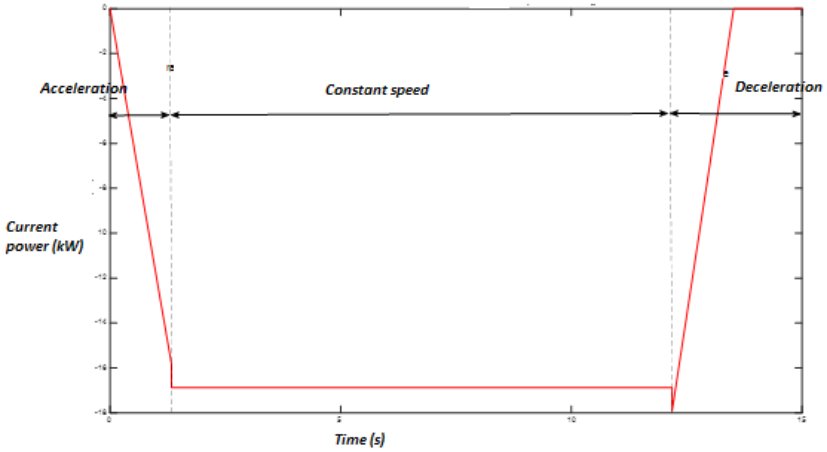

Fig. 8 – Engine power in acceleration, constant speed and deceleration when lowering the hoisted carriage of the SR machine. Source: own research

We will then create a numerical model to analyse the values of decision variables in objective function (minimisation of electricity consumption and consequently CO_2 emissions) in the Matlab software. In the existing model, we will propose a new storage strategy while considering the material throughput capacity and material storage location.

4 RESULTS

On the basis of the suggested methodology and the enclosed literature overview, we set the framework of the design and optimisation model of automated storage and retrieval systems for extremely heavy and large loads.

During the design and optimisation processes of our model, we will use the Matlab and Simulink software. When setting up the model, we will first define all input and output variables and constants. The constant value entering into the model will be the required or desired throughput capacity of the storage and retrieval system, which will be calculated on the basis of company data. The input variables will refer to the kinematic model of the SR machine travel at steady speed, acceleration and deceleration (the speed of the SR machine in horizontal and vertical direction, the accelerations of the SR machine in horizontal and vertical direction) as well as the length, height and width of the storage unit. On the basis of the input variable optimisation, we will calculate the output variables that include the engine power required to

move the SR machine as well as the power consumption and energy regeneration of the SR machine. The minimisation of energy regeneration will also be our objective function.

This research will result in a design and optimisation model of an automated storage and retrieval system for extremely heavy and large loads with the use of the automated SR machine. Given the required throughput capacity of a storage unit, we will minimise the electricity consumption of the SR machine by optimising the decision variables (the shape of the storage rack – length, width and height, and kinematic parameters of the SR machine – speed, acceleration) while considering the energy regeneration. We will then propose a new storage strategy in the existing model while considering the material throughput capacity (loads with higher throughput capacity will be stored closer to the input/output storage location) and its storage location (loads with higher throughput capacity will be stored closer to the input/output storage location). This is how we will further minimise the electricity consumption of the SR machine operation.

On the basis of the framework above, we prepared a flow chart that enters the input and output data into the suggested design and optimisation model of automated storage and retrieval systems for extremely heavy and large loads.

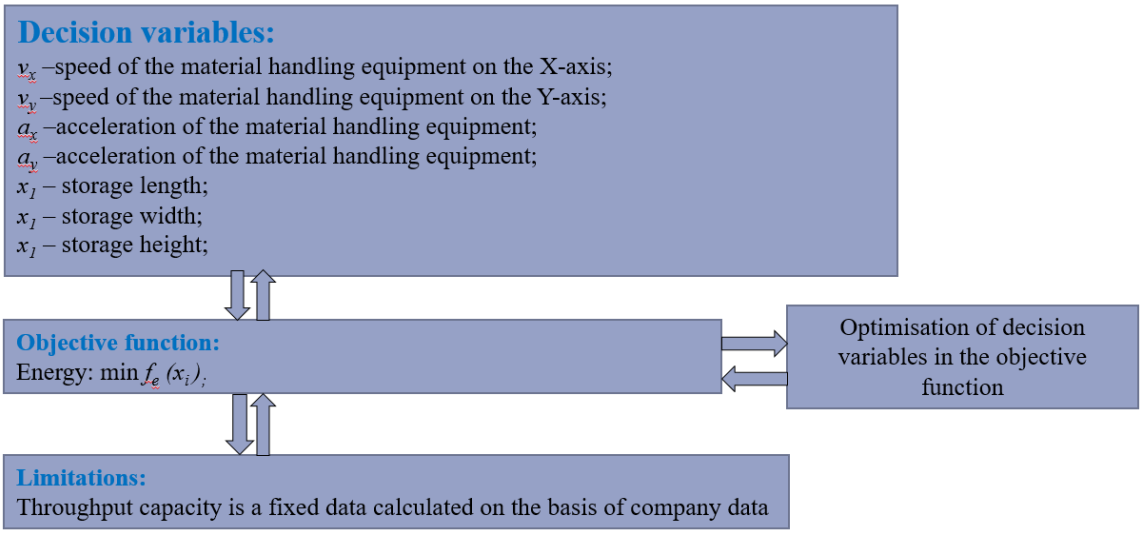

Fig. 9 – Model of an automated storage and retrieval system for extremely heavy and large loads. Source: own research

We anticipate the following original scientific contributions of the research:

We will present a new model of design and optimisation of automated storage and retrieval systems for extremely heavy and large loads to the scientific and professional audiences.

The process of designing a model of automated storage and retrieval system for heavy and large loads will be based on the objective function optimisation (minimisation of the electricity consumption and consequently the CO_2 emissions) while considering the achievement of the required storage system throughput capacity.

By designing and optimising a model for extremely heavy and large loads, this research will connect the throughput capacity/energy consumption with storage strategy.

We will analyse the impact of values of decision variables (speed and acceleration of the SR machine, the shape of the storage rack, the TSU weight) in the objective function of the SR machine electricity consumption.

We will present the (electrical) power consumption and define the impact of energy regeneration in case of horizontal deceleration of the SR machine and vertical movement (lowering) of its hoisted carriage.

We will set out the most efficient storage and retrieval strategy for cassettes with steel profile bundles that will base on the item similarity, cargo frequency, the weight of the steel profiles etc.

5 DISCUSSION

With an extensive literature overview, we got insight into the state of research studies in the area of extremely heavy and long unit loads as well as analytical and numerical models that are essential for our research from the point of view of storage system planning (the calculation of the storage system throughput capacity on the basis of kinematic parameters of the SR machine, the shape of the storage rack and the use of storage strategy as well as the calculation of the electricity (regeneration) consumption). We presented a framework for building a design and optimisation model of automated storage and retrieval system for extremely heavy and long unit loads with the use of the automated SR machine that will set the foundations for future research work in the doctoral dissertation. On the basis of scientific knowledge in literature, we set the framework of analytical modelling (analytical expressions to calculate the throughput capacity and storage rack shape, definition of kinematic characteristics of the SR machine, identification of engine power, electricity consumption and regeneration) and the relations between individual expressions. This is followed by the development of a numerical model for analysing the values of decision variables in the objective function in the Matlab software and the optimisation of an existing model with a new storage strategy.

6 CONCLUSION

The design and optimisation model of automated storage and retrieval system for extremely heavy and long unit loads with the use of the automated SR machine will fill a large research gap in scientific literature. We will connect the throughput capacity and energy consumption with storage strategy by designing and optimising a model for extremely heavy and long loads. The optimisation of the aforementioned criteria is essential to achieve a high-tech system with minimal costs of storage operation. Recording the newly acquired knowledge that is based on real data from a company will also present an important tool in practice that will help designers of storage systems in the area of extremely heavy and long loads.

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CASE STUDY ON RISK MANAGEMENT AND RISK EVALUATION IN ERGONOMICS

Miroslav Bednář

Abstract

The article is about assessing ergonomic concerns at the injection moulding machine's workplace, which is used to make foam components for automobile interiors. The risk evaluation included RULA assessments and methodologies for analysing working positions in accordance with current legislation. Simultaneously, while exercising with the upper limbs, the muscle stress on the forearm was assessed, all in accordance with legal requirements. Local muscle loading was measured using integrated electromyography. The investigations were carried out using the Tecnomatix Jack software application.

Keywords: *ergonomics, RULA, musculoskeletal disease, evaluation, rationalization*

1 INTRODUCTION

In recent years, there has been a lot of focus on improving the working environment. Despite the advancement of robotics, science and technology bring new methods and possibilities to facilitate the work of people, who remain a vital element of production. Nowadays, industrial firms are largely concerned with workplace organization and the removal of potential hazards that could result in, for example, accidents or occupational disorders. Unsuitable working conditions, as well as the inefficient output that results, can put many industrial businesses at a competitive disadvantage. The adoption of ergonomic principles is one technique to improve the working environment. The work's main goal is to rationalize analysed workplaces in an industrial organization using specified ergonomic methodologies and identify problematic areas.

2 LITERATURE REVIEW

Modern ergonomic risk assessment methods are a tool for postural analysis and allow early identification and comprehensive assessment of the risk of musculoskeletal damage. These methods may become significant components in the prevention of musculoskeletal disorders; they are quick, simple and inexpensive, so it is beneficial and desirable that they are used as standard in ergonomic risk assessment at work (Bevan, 2015). The main reason why companies should be concerned about the health of their employees in the first place is the development of musculoskeletal disorders and the potential for occupational disease (Nunes, 2009). Musculoskeletal disorders (MSDs) are the most common work-related health problems in Europe and accounted for more than 50% of all reported work-related health problems in 15 European Union (EU) countries in 2020 (Govaerts et al., 2021). MSDs are among the most common problems related to work activities. They affect millions of workers across Europe and cost employers billions of euros. At the same time, there is emerging evidence that these disorders are also related to psychosocial risk factors, such as high job demands, low levels of autonomy, and low job satisfaction (Dul & Neumann, 2009).

3 METHODOLOGY

The main aim of this work is to analyse workplaces using ergonomic methods to identify problematic areas and subsequently to rationalise workplaces in an industrial enterprise. It is essential to introduce modern methods of ergonomic safety risk assessment to simplify and facilitate MSD risk assessment and to allow a comprehensive assessment of the different risk factors at work. We have decided to use RULA analysis to find ergonomics problems. The risk assessment methods are categorical, semi-quantitative and they tell us whether ergonomic risk is present at work and whether preventive action is needed. (Gómez-Galán et al., 2020) These methods for the assessment of ergonomic risks at work are not yet sufficiently used in industrial enterprises or by hygiene stations. However, it would be beneficial and desirable to put them into practice, as they are an important component in the prevention of MSDs and they are quick, simple and inexpensive (only pencil and paper are needed). RULA was used in the study, and it was developed in Tecnomatix Jack software.

4 RESULTS

The monitoring and data collection took place in an industrial company whose produce interior components for cars. The worker moves freely between the workstations and performs all work standing up. The standard production per shift is a total of 200 pieces per worker. The workplace consists of a complex pressing machine. The standard production per shift is a total of 200 pieces per worker. The workplace consists of a complex pressing machine, which is equipped with a yellow safety cage with barriers. Among other things, there are two metal racks with pre-pressed products, which are further processed on these presses. There is also an additional rack for finished foamed mouldings. Using a spray gun, the mould is coated with non-stick lubricant, the semi-finished product is inserted, the machine is started and then the semi-finished product is removed and placed in the rack. According to the overall RULA score, the worst result was achieved for position 2, which is the removal of the finished product from the steel mould. According to observations and interviews in the plant, it can be confidently confirmed and concluded that this is the most physically demanding position and also very risky from a safety point of view. The results for the 5th percentile were worse for positions 1 and 3 than for the 95th percentile. The most acceptable results of the analysis were obtained for Position 1, where the 95th percentile worker achieved a RULA score of 3, which does not represent a high level of risk. However, there is potential for improvement and therefore actions will be proposed for this position, see section 7.3. The results for position 4 are concerning as the overall RULA score for both percentiles was 7. Based on the results of the analyses, it is evident that the current state of the work-place is not satisfactory in terms of ergonomics and there are deficiencies. Workers are physically overworked in some positions. In addition, the use of the box to stand on, which is unstable and poses a risk of work-related injury, appears to be a significant safety risk.

Fig. 1 – Positions. Source: own research

5 DISCUSSION & CONCLUSION

If workspaces do not follow appropriate equipment and workers are overworked, manufacturing businesses will incur a certain cost. Regular medical exams, breaks, worker rotation, and workplace rationalization are all part of the answer. Occupational diseases that already exist in ergonomically unsuited workplaces result in considerably greater expenditures for various types of compensating for workers' health issues (Hulshof et al., 2021). It is critical to analyse and improve workplace conditions on a regular basis in order to minimize these dangers. This enhancement improves worker comfort in the workplace and, more importantly, eliminates the previously indicated cost hazards. Ergonomics is an important part of any workplace and it is essential that businesses focus on it.

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MODEL OF COMPLEX DIAGNOSTICS OF ERGONOMIC FACTORS IN MANUFACTURING COMPANIES

Jan Holoči

Abstract

At present, humanity is on the threshold of a new, more technologically advanced era, which is spreading globally across manufacturing and non-manufacturing companies with the implementation of new technologies within Industry 4.0. On the other hand, few individuals realise that these radical innovations and changes in processes arise primarily because of us, customers (consumers). Unfortunately, due to this blindness of today, the worker is increasingly exposed to increasing demands for qualifications, performance and work at a forced pace, which leads to injuries and long-term productivity losses due to unsatisfactory working conditions. Motion analysis system (MAS), together with Czech legislation, can analyse the movements of workers thanks to sensors and cameras in real-time and thus can identify potential threats and bottlenecks for further optimisation.

Keywords: *Ergonomics, MOCAP, MAS, risk factors, Industry 4.0*

1 INTRODUCTION

The Motion Analysis System, or MAS, is a unique and new hardware/software technology that can capture and analyse the operator during manufacturing and assembly operations. MAS was founded by (Bortolini et al., 2020; Bortolini et al., 2018). The MAS is working on optical MOCAP technology without markers. Thanks to this technology, the worker's natural movements can be detected in real-time, as it is not limited by any material sensors located on his body. The MAS has two main perspectives: productive and ergonomics. The productive perspective focuses mainly on the optimisation of individual activities, movement in space (spaghetti diagram) and evaluation of individual activities (How much % of the time the operator spends assembling, manipulating, waiting, etc.) The second perspective is devoted to ergonomics movements and positions the operator occupies during a classic work shift. In my scientific research, I would like to combine these two perspectives (which will be upgraded to a higher level) with Czech legislation to ensure complex screening/evaluation software/hardware architecture in the Czech Republic.

2 LITERATURE REVIEW

The MAS is based on MOCAP technologies. Duffy (2007) was the first to create a digital concept of the operator's human body, which recorded all movements during assembly activities. At the same time, they identified three basic MOCAP technologies: Optical (with markers), inertial (with markers) and optical (without markers = MAS). Morrow et al. (2017) used inertial MOCAP technology in healthcare to identify risk positions in invasive training surgery. In contrast, Puthenveetil et al. (2015) used a more technologically advanced optical MOCAP with markers to analyse the movements of workers during assembly operations in aircraft production. The captured data was further used in Tecnomatix Jack software. Optical MOCAP without markers was used by Agethen et al. (2016) in the automotive industry to identify bottlenecks (especially handling = LEAN waste).

3 METHODOLOGY

This literary research forms the basis for my scientific work, the aim of which is to connect the already established MAS technology with Czech legislation so that when screening operators, it is possible to identify not only non-ergonomic working positions but also individual risk factors that are enshrined in Czech legislation, which are further used to categorise works. The main goal can therefore be defined as: "Parameterisation of data diagnostics for the field of ergonomics by using software support of data diagnostics of physical activity and ergonomic factors influencing the productivity of workers."

4 RESULTS

After the completion of screening activities, the MAS is ready to analyse the obtained data. Figure 1 shows the classic layout of MAS software/hardware in the conditions of the industrial workplace. The data are evaluated from both a productive and ergonomic perspective. Based on user requirements, the MAS can implement various methods and techniques that can best identify potential bottlenecks or health risks. In terms of ergonomics, the MAS can apply methods such as NIOSH, RULA, REBA, OWAS, EAWS etc. On the contrary, in terms of productivity, the MAS focuses primarily on identifying bottlenecks through the LEAN methodology. Based on the screening, MAS can create a time snapshot of the operator together with a spaghetti diagram. Outputs from both of these perspectives should, in practice, offer manufacturing companies a comprehensive solution for non-ergonomic risk positions but also solutions for potential bottlenecks.

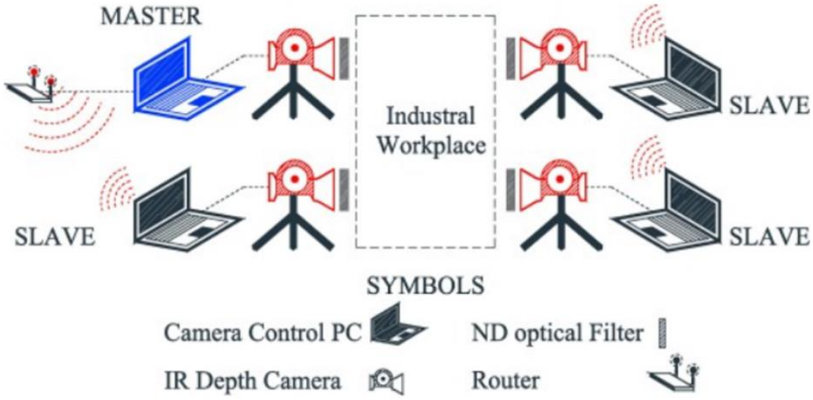

Fig. 1 – Typical MAS layout. Source: Bortolini et al. (2020)

5 DISCUSSION & CONCLUSION

The MAS is a comprehensive analytical tool that offers a wide range of practical applications. It could be said that the current form of the MAS is such a pioneer of new technologies that, after transferring reality to a virtual environment, can identify potential risks but also adequately eliminate them. As part of my research, I am convinced that the MAS has not yet reached its full potential. In the area of productive perspective, other LEAN methods can be implemented in the software, such as SMED, 3M, 5S, 7 + 1 types of waste. I see another great potential, especially in the Czech Republic, where the legislation itself defines individual risk factors, through which the works are subsequently categorised. At the same time, this MAS system could be improved in the field of technology, where new sensors can be implemented, for example, the operator's heart rate, an accelerometer to identify acceleration of individual body parts, pedometer to identify distance travelled, sensors of noise, vibration, temperature. All of these technologies and potential improvements can take the MAS to a whole new level. In

addition to ergonomics and general optimisation of work and the workplace, long-term and continuous operator performance can be ensured while minimising possible injuries and threats.

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DIGITAL TRANSFORMATION OF THE AGRICULTURE SECTOR

Larisa Hrustek

Abstract

Digital technologies are an unavoidable backbone of development and it is important to learn to manage them competitively and collaboratively. Scientific and professional literature on the application of technologies in the agricultural sector is limited to the identified opportunities, benefits, and barriers. The problems caused by the disruptions and the expectations regarding the contribution to the achievement of the sustainability goals represent an increasing challenge for the agricultural sector.

Keywords: *digital technologies, agriculture sector, disruption, sustainability*

1 INTRODUCTION

The problems caused by the disruptions and the expectations regarding the contribution to the achievement of the sustainability goals represent an increasing challenge for the agricultural sector (Nyam et al., 2021). Global trends in the development of contemporary technologies and new business concepts provide an opportunity to solve problems in the agricultural sector, which is significantly sensitive and at the same time the most conservative in relation to progressive technological development (Mironkina et al., 2020). The application of digital technologies should provide to address disruptions in the agricultural sector and contribute to the promotion of best management practices, practices crucial for sustainable development, and promotion of effective resource management (Lanucara et al., 2020; Ningrum et al., 2021; Willenbrink et al., 2021), but this field is not yet investigated (Fig. 1). This research is a preliminary report on disruptions in the agricultural sector and the opportunities brought by digital technologies to solve problems. Based on the results of the literature review, research questions for future work are defined as follows: RQ (1): What problems are caused by disruption and how to identify the space and/or the need to improve agricultural processes through the application of digital technologies?; RQ (2): How to analyse and evaluate technologies that will help the farm to adapt business processes?; RQ (3): How to use digital technologies to increase the adaptability of the agricultural sector on disruptions and sustainability.

2 LITERATURE REVIEW

Current research highlights the opportunities and benefits that digital technologies provide in the agricultural sector. The application of technologies enables quality management of agricultural processes, resources, and data, which enables the detection of problems, useful practices, and the exchange of experiences (López-Morales et al., 2020). Nevertheless, the application of digital technologies is at a low level (Groher et al., 2020), although there is huge potential. Some of the identified barriers are high investment costs, lack of interest and awareness of benefits, and lack of state support (Kumar et al., 2021). Challenges such as high business vulnerability, strong dependence on external factors, and achieving the goals of sustainability concepts are increasing. This results in two-way and confronted demands in this sector.

3 METHODOLOGY

Tab. 1 – Logical research matrix. Source: own research

RQ	Goal	Methods
RQ1	Identify problems caused by disruption and recognize space and/or needs to improve agricultural processes using digital technologies	Analysis of scientific and professional literature; Interview with experts; Questionnaire and interview of agricultural holdings and farms
RQ2	Define the features and procedure for the assessment of digital technologies in the agricultural sector	Analysis of scientific and professional literature; Interview with experts; Questionnaire and interview of agricultural holdings and farms
RQ3	Develop a framework and recommendations for increasing the adaptability of agricultural business processes in case of disturbances and sustainability management in the sector	Modelling; Illustrative case study

4 RESULTS

Future work will focus on research of managing disruption in the agricultural sector driven by digital technologies (Tab. 1). Based on the literature analysis and interviews of experts of the Agricultural Advisory Service and agricultural holdings, key problems in operations and needs for improvement will be explored. The methods of assessing the level of application of digital technologies and barriers that prevent their application in the agricultural sector will be investigated. The features and procedure for assessment of technologies in the case of the identified problem will be discussed and defined with experts. Based on the first two parts of the research, will be developed framework and defined recommendations that enable the identification of the most appropriate technology for solving problems and contribute to the achievement of sustainability.

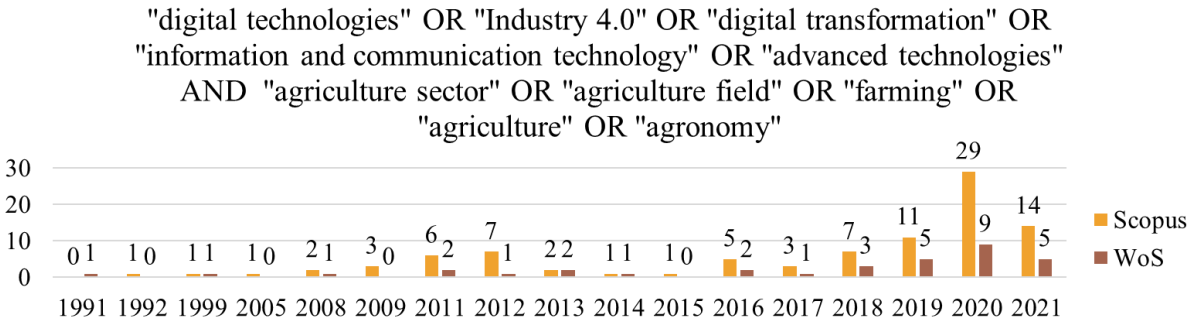

Fig. 1 – The number of articles in Scopus and WoS on the query. Source: own research

5 DISCUSSION & CONCLUSION

The agricultural sector is significantly affected by disruptions and global challenges that cause business problems. Difficult control of operations in the agricultural sector and a significant impact on environmental, economic, and social sustainability have been recognized in the scientific community, and agricultural policies of the European Union and countries created for the coming period are aimed at managing this challenging field. Great attention will be paid to increasing the adaptability of the agricultural sector to disruptions and the contribution to sustainability, based on the application of digital technologies (Zoll et al., 2019). In order to create the conditions for this, it is necessary to identify business problems caused by disturbances, identify space and/or needs for improvement, and identify technology that will contribute to the improvement of agricultural processes and the achievement of sustainability. For the purpose to achieve quality and relevant research results, the research will include

experts from the field of agriculture, such as the agricultural advisory service, the scientific community, i.e. the agricultural faculties and agricultural business. The results of the research will serve as a guide in the selection of digital technologies in agriculture, with the potential of application in other industries.

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STUDY OF RUBBER COMPOUNDS USING SMALL-ANGLE X-RAY SCATTERING

David Jaška

Abstract

The thesis focuses on the structure of rubber compounds based on styrene-butadiene rubber filled by silica particles modified by organosilanes. The prepared rubber compounds were analysed by small-angle X-ray scattering. The influence of the size of silica aggregates on the mechanical properties was studied. Presented results show that the size of silica aggregates in rubber compounds is affected by the organosilane type and its content.

Keywords: *styrene-butadiene rubber, silica, silanization, structure, aggregate, small-angle X-ray scattering*

1 INTRODUCTION

Today, elastomeric materials are irreplaceable raw materials in the production of products in many different industries. The best-known and most important products are tires for cars and trucks, which are subject to very high demands in terms of composition and construction. As with plastics, in the case of rubber compounds, it is possible to use additives to influence the resulting properties of the products. The final mechanical properties of the vulcanizate can be influenced by choosing the right filler and its amount. (Ciesielski, 1999; Maláč, 2005)

This work deals with the description of the structure of rubber compounds filled by silica particles modified by organosilanes (TESPD – Bis[3-(triethoxysilyl)propyl] tetrasulfide; Octeo – Octyltriethoxysilane; Pteo – Propyltriethoxysilane. The silica surface contains Si-OH silanol groups. These are reactive and are used for modification reactions with organosilanes. A chemical process called silanization should ensure greater compatibility between the filler and the rubber, which should lead to better reinforcement of the vulcanizates. (Maláč, 2005; Limper, 2012; Ash & Ash, 2013)

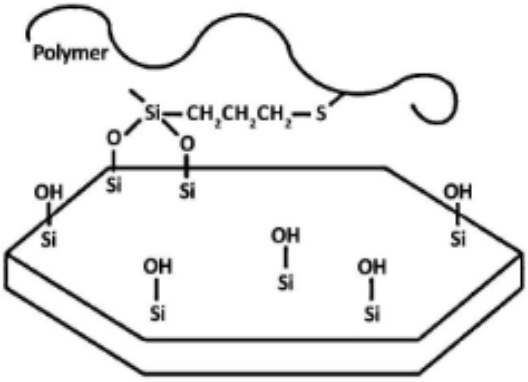

Fig. 1 – Interaction of silane with rubber. Source: Maláč (2005)

2 LITERATURE REVIEW

Many studies have been published on the effect of different organosilanes on different types of rubbers. It has been reported that the addition of organosilane, e.g., (TESPT), into silica-filled rubber, not only improves silica dispersion but also enhances rubber–silica interaction (Goerl

et al., 1997). Bandyopadhyay et al. (1996) confirmed that APTES acts as a coupling agent for silica-filled NBR compounds. Siriwong et al. (2014) decrease the aggregate size of silica by hydrophobizing with CPTES.

3 METHODOLOGY

Compounds were made by three-step mixing in a kneader. The formulation of the compounds is shown in tables. Each compound was tested on an MDR device to determine the optimum vulcanization of t90. Test specimens were prepared by pressing.

Tab. 1 – Silane concentrations in phf units. Source: own research

Comp.	Octeo	Pteo	TESPD
1	0	0	0
2	1	0.7	1.7
3	2	1.5	3.4
4	4	3.0	6.8
5	6	4.5	10.3
6	8	6.0	13.8
7	10	7.4	17.3
8	15	11.1	26.1
9	30	22.0	45.0

Tab. 2 – Compound recipes. Source: own research

	PHR	PHR
SSBR	100	100
Silica	30	95
Silane	Table 1	Table 1
Oil	35	35
Vax	2	2
6PPD	2	2
Zinc stearate	2.5	2.5
DPG	2	2
CBS	1.6	1.6
Sulfur	2	2

SAXS analysis was performed on a SAXSpace from Anton Paar. The device was equipped with an X-ray lamp providing monochromatic CuKα radiation. The collimation system was set in line mode. The generator operated with a voltage U = 40 kV and current I = 50 mA. The distance of the sample from the detector was set to the maximum possible value of 307.3 mm. The total exposure time was 7.5 minutes. Data analysis was performed in SAXSanalysis software.

All compounds were subjected to a tensile test on a Tensometer T10D. Vane-shaped specimens with a working length of 20 mm and a width of 4 mm were cut from 1 mm compacts. 6 test specimens corresponded to one material. The uniaxial thrust was mediated by the movement of the upper jaw at a speed of 50 mm/s.

4 RESULTS

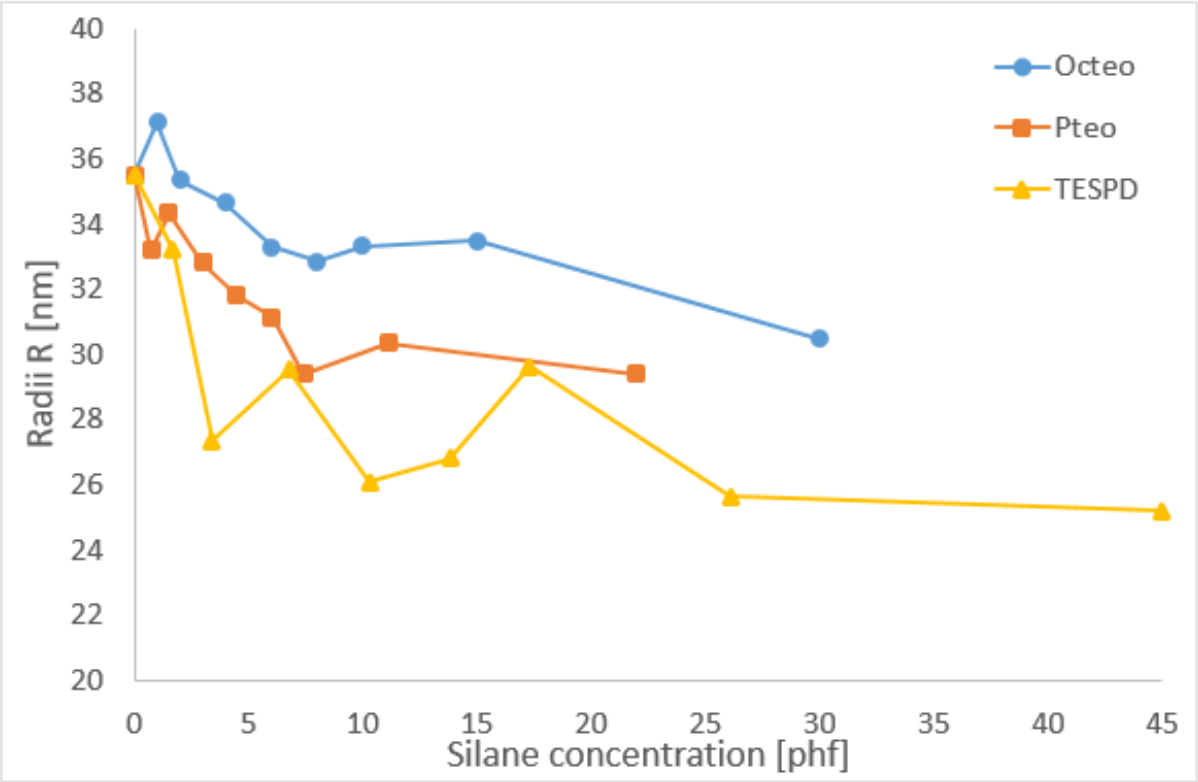

Fig. 2 – Radii of silica aggregates as a function of silane concentration, amount of silica: 95 phr (note: connecting the points with a curve is only a guide for the eyes). Source: own research

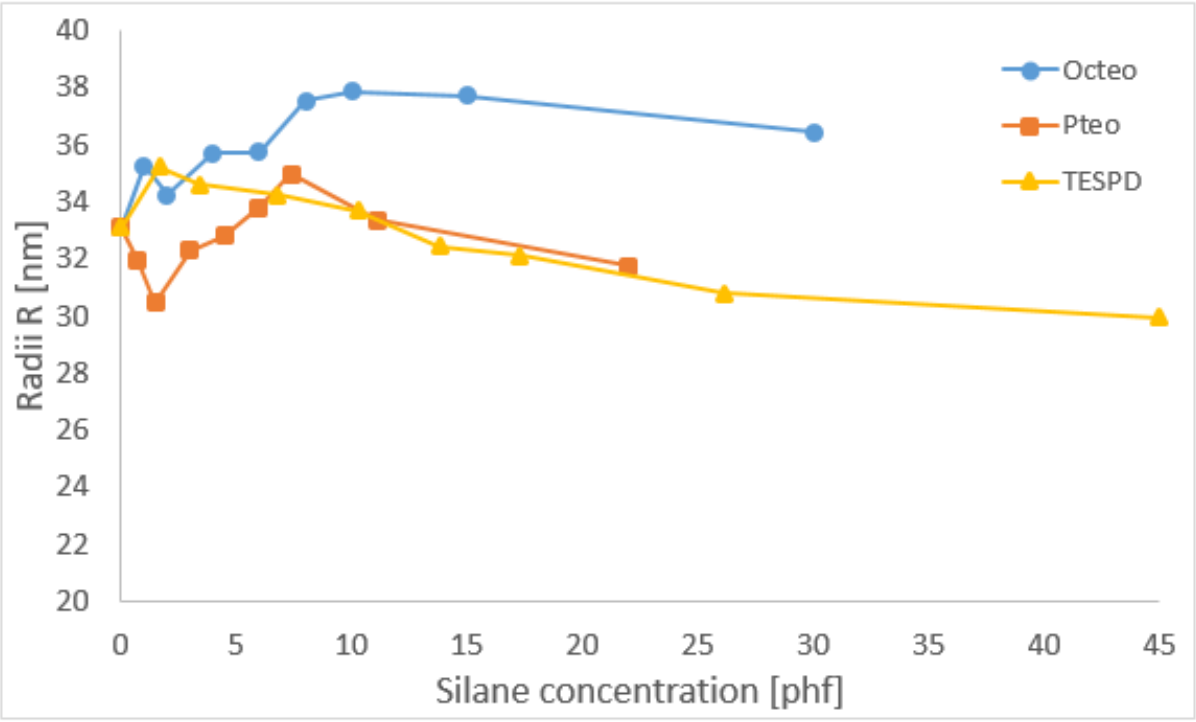

Fig. 3 – Radii of silica aggregates as a function of silane concentration, amount of silica: 30 phr (note: connecting the points with a curve is only a guide for the eyes). Source: own research

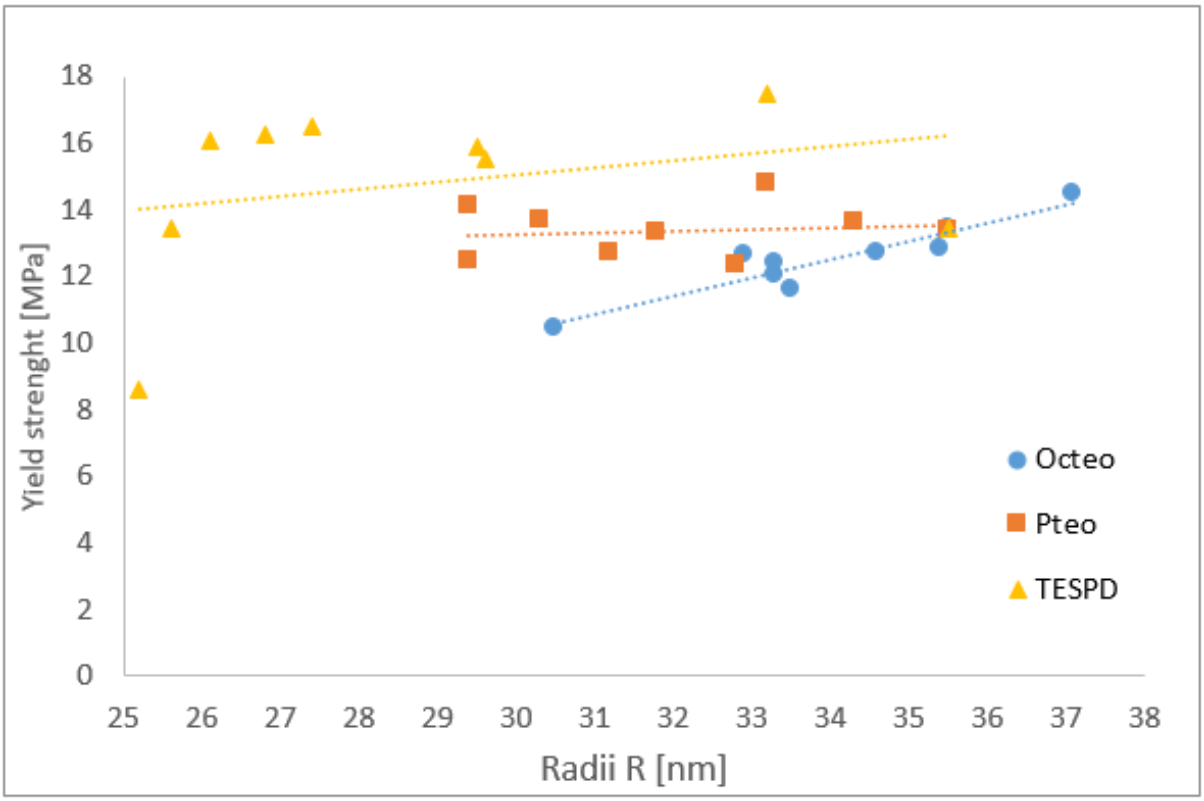

Fig. 4 – Dependence of the yield strength on the radius of silica aggregates, amount of silica: 95 phr. Source: own research

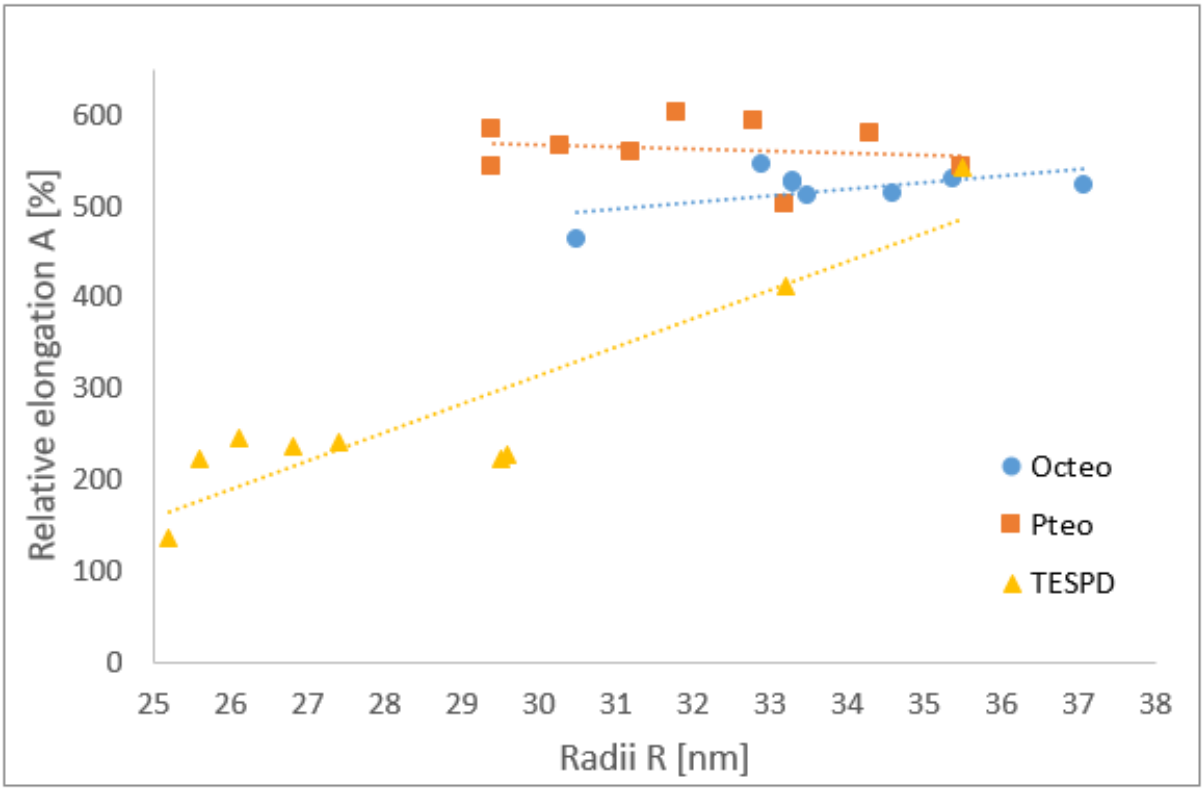

Fig. 5 – Dependence of the relative elongation on the radius of the silica aggregates, amount of silica: 95 phr. Source: own research

5 DISCUSSION & CONCLUSION

The results showed the influence of silanization of silica on the size of the formed aggregates. These decrease with increasing concentration of silanes in the compound. The largest differences can be observed for compounds with 95 phr of silica. For low-fill compounds with 30 phr of silica, this trend can only be observed for compounds containing TESPD. The relative elongation at break does not change much for mixtures with 90 phr of silica, except mixtures with TESPD, where the decreasing radii of the aggregates caused a rapid decrease in the relative elongation. No significant changes are observed in the case of the yield strength results. Similar trends in the results of mechanical behaviour were observed in the case of compounds with 30 phr of silica. It can be stated that the organosilane TESPD has the greatest influence on the structure of the filler and mechanical properties. Compounds with this type of silane show the largest differences in the average sizes of the aggregates formed and the largest differences in mechanical behaviour. Silanization of silica resulted in smaller aggregates, leading to better mechanical properties.

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INTERREG V-A SLOVENSKÁ REPUBLIKA ČESKÁ REPUBLIKA SK-CZ 14-20

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EVALUATION OF FOREARM MUSCLE LOAD IN THE CASE OF FOREARM FLEXION AND EXTENSION

Ilona Kačerová

Abstract

The study deals with research on the physical load of production workers. The main goal is to analyse the connections between position of the upper limbs and the loads handled. The measurements of the local muscular load with the iEMG were used. The position of the shoulder in different movements (flexion and abduction) were analysed. Experiments were performed on 180 participants. The results show that the muscle loading of the forearm is lower in case of flexion than in the case of abduction.

Keywords: *ergonomics, iEMG, Holter, flexor, extensor, local muscular load*

1 INTRODUCTION

In today's era of extensive robotization, it may seem that the role of humans in production is becoming irrelevant, but the opposite is true, because humans will never disappear from the work process completely, but will occupy different jobs than before. Today, there are many laws, standards and regulations that protect workers against overwork, whether it is chemical, biological or physical. One of the most comprehensive regulations in the Czech Republic is Regulation No. 361/2007 Coll., which contains, among other things, limits on the physical load of workers that should be observed during a work shift; if the limits are not observed, workers may develop occupational diseases. It is precisely the overloading of workers and the possible development of occupational disease that is a major problem nowadays.

2 LITERATURE REVIEW

The Scopus and Web of science databases were used for the literature search using the main keywords EMG and shoulder, a total of 113 papers were found in the Scopus database and 112 papers in the WOS. From which only relevant papers related to industrial engineering were then filtered, resulting in 30 papers. Subsequently, the search was supplemented with other relevant articles - mainly publications related to basic information on integrated electromyography in industry, the use of dynamometer in ergonomics or studies focusing on musculoskeletal disorders caused by repetitive movements of the upper limbs. To determine the appropriate measurement methodology, we drew on the experience of experts in the field of local muscle loading (De Luca, 1997) who have addressed similar relationships between different muscles and work positions (Farooq & Khan, 2014; Brookham et al., 2010; Mukhopadhyay et al., 2007a,b). Maximal muscle strength was measured using a Jamar Plus dynamometer while respecting certain rules (Duque et al., 1995).

3 METHODOLOGY

In the experiment, the movement of both upper limbs was observed with a detailed focus on the working position, the weight of the manipulated load and the magnitude of the muscle load. The research focused on the dynamic activity of the upper limbs, in six positions of the shoulder joint - Shoulder joint flexion 0°- 40°, 0°- 60°, 0°- 80° and shoulder joint abduction 0°- 40°, 0°- 60°, 0°- 80°. All movements were performed standing up. The working positions were

investigated with different weights of the manipulated load (weights) - 0 kg, 2 kg, 4 kg, 6 kg, 8 kg, 10 kg. Women manipulated only weights up to 6 kg in the experiment. Due to the nature of the work and the connection to industrial plants, all weights were handled in the experiment by overhand grip.

4 RESULTS

Experiments were conducted on 180 participants (age 20 – 68, women/men). The measurements were performed respecting the standard operating procedure for measuring local muscle load. In 56 cases normality was rejected, therefore, non-parametric tests were used. Non-parametric paired test, one-sided - Mann Whitney was carried out for all weights (0, 2, 4, 6, 8, 10 kg), also for all angles (40°, 60°, 80°) and for right/left hand. A total of 36 tests were performed for each muscle. We tested the null hypothesis H0: "muscle loading is the same in the case of forearm and upper arm" against the alternative HA: "muscle loading of forearm is lower in case of flexion than in the case of abduction". To show that H0 does not apply, the p-value must be less than 5% (the established significance level). This hypothesis was not confirmed in the zero-weight case. Example of statistical evaluation for right upper arm in the position of 60° is in the table. At the same time, submissive upper limb extensors were refuted in the case of maximum weight (10 kg). In all other cases the hypothesis was confirmed. Which proves that the muscle load in flexion is lower than in abduction.

Tab. 1 – Statistical evaluation for right upper arm in the position of 60°. Source: own research

RUA 60°	Median(flexion)	Median(abduction)	Difference	p-value
0 Kg	2,546	2,248	0,298	0,79
2 Kg	13,913	16,253	-2,340	3,07E-20
4 Kg	17,835	23,199	-5,365	1,78E-20
6 Kg	22,523	28,344	-5,820	4,79E-21
8 Kg	28,905	32,466	-3,561	3,32E-08
10 Kg	32,958	35,643	-2,685	1,00E-07

5 DISCUSSION & CONCLUSION

Research has shown that the muscle load on the forearm in the shoulder flexion position is lower than in the abduction position. The paper also confirmed consistency with previous research and professional papers. For example, the relationship between the average Fmax of local muscular load and the strength of the palmar grip was clarified. Based on these results, it is possible to predict the local muscle load for specific operations during manual activities.

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NONISOTHERMAL CRYSTALLIZATION OF BLENDS OF LINEAR AND BRANCHED POLYPROPYLENE WITH BETA-NUCLEATING AGENT

Michal Kudláček

Abstract

Crystallization of polymer blends of linear (L-PP) and long-chain branched polypropylene (LCB-PP) with beta-nucleating agent was studied. Samples were prepared in handpress from pre-existing blends used in Gajzlerová et al. (2020) for easier manipulation. During every thermal treatment, each sample was first heated to 220°C for 5 minutes to erase any thermal memory. The effect of different content of L-PP and LCB-PP on morphology was evaluated using SEM, DSC and wide-angle x-ray diffraction. These methods provided wide spectrum of results, concluding that blends with low percentage of LCB-PP (SM-1-N and SM-1-N, see further in the text) are the ones, that could see industrial use as a replacement to linear polypropylene because of their enhanced processing parameters.

Keywords: *polypropylene, beta-nucleation, long-chain branched polypropylene, polymer blends*

1 INTRODUCTION

Primary goal of creating polymer blends is to achieve material characteristics, which would otherwise be impossible with use of only one type of material. In case of polypropylene (PP), material characteristics of linear variant are highly desired, while its processing is difficult due to low melt strength. Addition of long-chain branched polypropylene enhances rheological properties, thus also enhancing its processing range (Cao et al., 2016). PP is polymorphic, thus its crystalline phase creates primarily three different modifications, α-phase, β-phase and γ-phase, as well as irregular smectic phase. Under normal processing conditions, only α-phase, which enhances stiffness, with very low percentage of γ-phase are created. This work is focused on inducing creation of β-phase, which greatly improves toughness and drawability, using β-specific nucleating agent NJ Star NU-100 in concentration of 0,03 wt. %. NJ Star NU-100 (Obadal et al., 2004), chemically N,N‘-dicyclohexylnaphtalene-2,6-dicarboxyamide, is commercially used semi-specific nucleating agent (Menyhárd et al., 2006), which primarily induces creation of β-phase with slight effect on creation of α-phase (Čermák et al., 2006; Kotek et al., 2002; Navratilova et al., 2021).

2 LITERATURE REVIEW

Long-chain branched polypropylene is generally known to enhance rheological properties, thus its addition to linear polypropylene opens up its field of applications, especially in blow moulding, thermoforming and foaming (Cao et al., 2016). It was also found by Tabatabaei et al. (2009), that even low amounts of LCB-PP greatly impact crystallization rate and crystallization degree due to increased nuclei sites. Published studies by Varga (1992) and Raab et al. (1998) shown that beta-phase in PP improves toughness of material, while decreasing its strength and stiffness.

3 METHODOLOGY

Materials used were LIN-PP (Borclean HC310BF, Borealis) and LCB-PP (Daploy WB140HMS, Borealis) as linear and branched polypropylene respectively. NJ Star NU-100 (Rika Int.) was used as β-specific nucleating agent. Thermal program for every measurement was heating up sample from 25°C to 220°C with hating rate 10°C/min and subsequently nonisothermally cooled with cooling rates of 2°C/min, 5°C/min, 10°C/min and 20°C/min. In case of DSC, 40°C/min cooling rate was used in addition to previously mentioned ones. For crystallization kinetics, DSC was performed nonisothermally (DSC 1, Mettler Toledo) on ~5mg samples in nitrogen atmosphere. For phase content evaluation, thermal cell WAXD was performed using Bragg-Bretano geometry in refraction mode with CuKα anode with Ni filter (λ = 0,154 nm, I = 30 mA, U = 40 kV) in angle range of 5°-30° (X'Pert PRO, PANanalytical) on 10x10x0,5mm samples. For morphological structure, optical microscopy with hot stage was performed (Olympus BX41-P, Olympus Corp.; Linkam TP 94, Linkam Scientific Instruments) as well as SEM on chemically etched samples from hot stage (Phenom Pro, Thermo Fisher Scientific).

Tab. 1 – Used blends. Source: own research

	L-PP-N	SM-1-N	SM-2-N	SM-5-N	SM-10-N	SM-20-N	SM-50-N	LCB-PP-N
LIN-PP	100	99	98	95	90	80	50	0
LCB-PP	0	1	2	5	10	20	50	100

4 RESULTS

Tab. 2 – Measured crystal size from SEM images. Source: own research

Blend	Cooling rate [°C/min]	Crystal size [μm]	Deviation [μm]
L-PP-N	2	26,75	± 6,27
	10	21,72	± 5,75
LCB-PP-N	2	3,06	± 1,64
	10	2,24	± 0,83
SM-1-N	2	15,92	± 3,08
	10	13,35	± 4,62
SM-10-N	2	11,87	± 2,68
	10	3,35	± 1,06

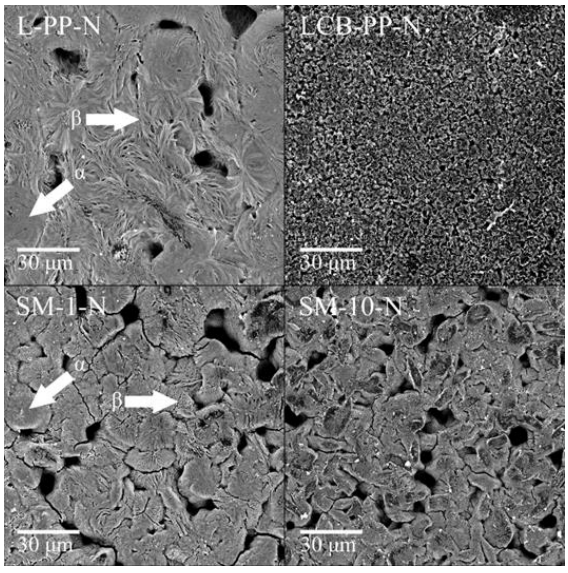

Fig. 1 – Morphological structure of blends prepared with cooling rate of 2°C/min from SEM. Source: own research

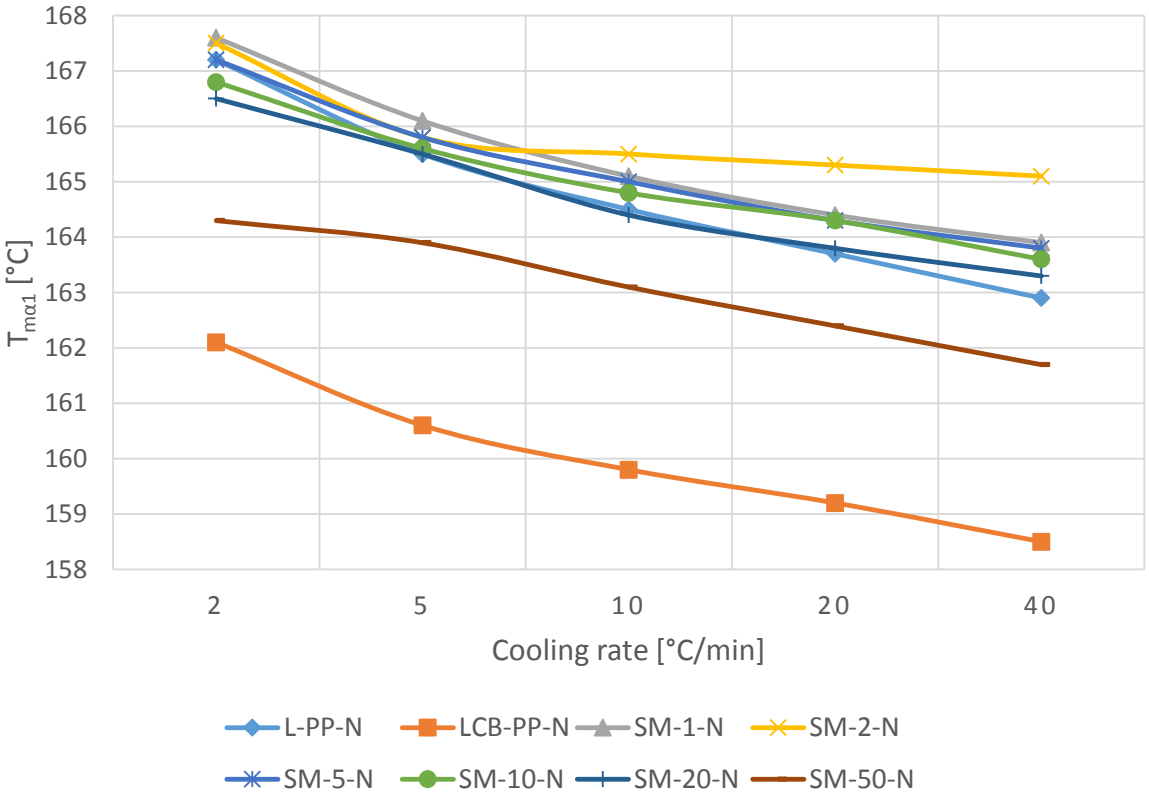

Fig. 2 – Melting temperature of α-phase obtained from DSC. Source: own research

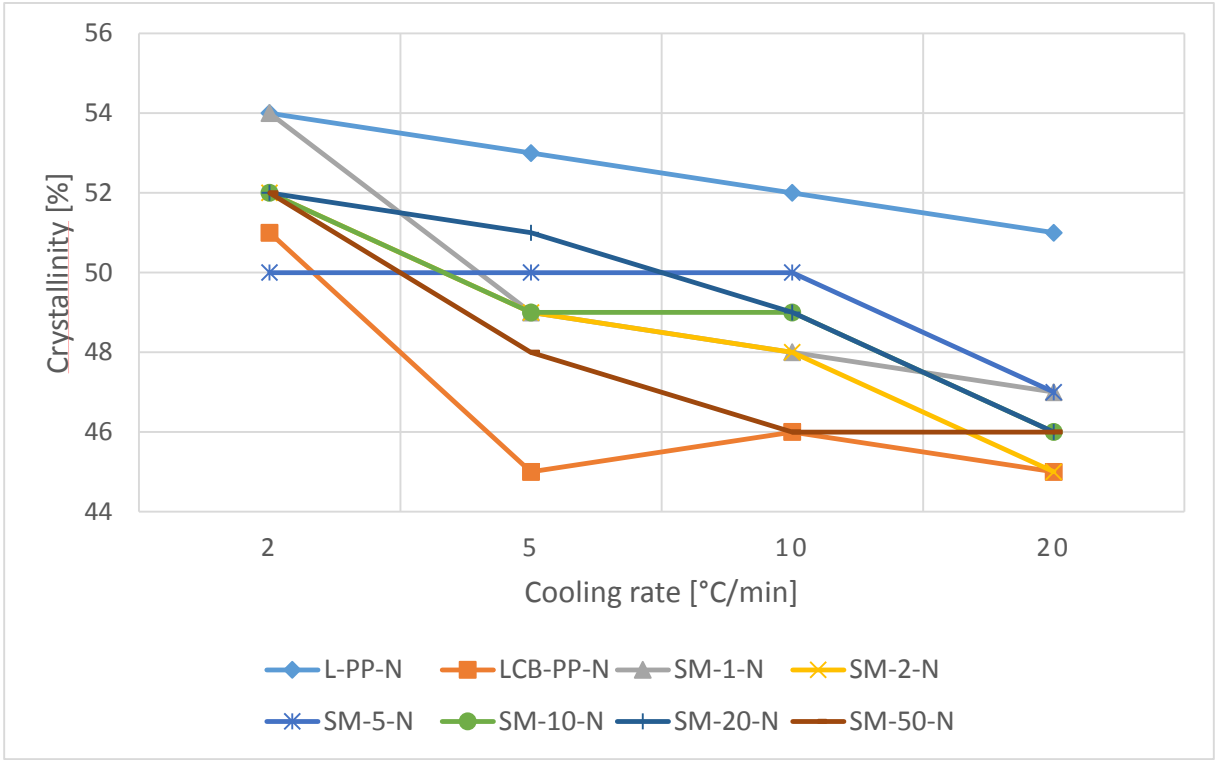

Fig. 3 – Crystallinity dependency on different cooling rates obtained from WAXD. Source: own research

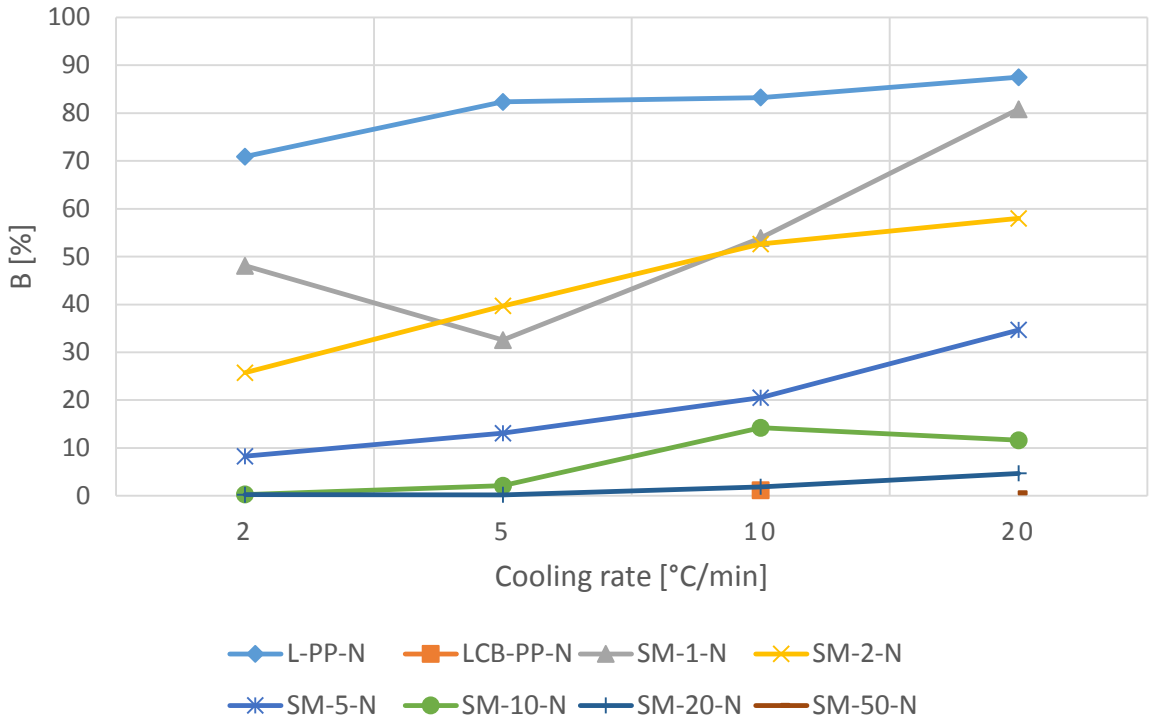

Fig. 4 – Content of β-phase in blends dependent on cooling rate obtained from WAXD. Source: own research

5 DISCUSSION & CONCLUSION

Addition of beta-nucleating agent was very effective in inducing creation of beta-phase in blends, especially in blends with low LCB-PP content. This trend could be explained by presence of long-chain branches, which function as self-nucleants inducing primarily alpha and gamma phase, as well as possibility of them being networked as a result of creation of branched polymer (radical mechanism using peroxides). Depending on their mechanical properties (which were not part of this thesis), blends with 1 wt. % and 2 wt. % content of long-chain branched polypropylene appears to be the most suited for commercial applications, primarily for their structural and material properties being very close to desired linear polypropylene, while being easier to process due to addition of LCB-PP.

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ACCOUNTING DIGITAL TRANSFORMATION INITIATIVES

Ana Kutnjak

Abstract

Accounting services (AS) achieve their success in the market, among other things, by constant innovation and focus on end users while meeting their needs. At the same time, their success is influenced by the way they appear on the market and their adaptation to market trends. The trend that is increasingly talked about is the digital transformation whose idea is not based strictly on technology, but its application in those business segments of AS where it will affect innovation and improve business performance in general.

Keywords: *digital transformation, accounting services, literature review, digital initiatives, business models, business performance*

1 INTRODUCTION

Digital transformation (DT) "is the profound transformation of business and organizational activities, processes, competencies and models to fully leverage the changes and opportunities of a mix of digital technologies and their accelerating impact across society in a strategic and prioritized way, with present and future shifts in mind,, (i-SCOOP, n.d.). DT allows organizations to incorporate new values into business through new business models, products or services that will be fully in line with customer requirements. Clear digital strategy, inclusion of all resources of the organization, quantitative measurement of success and continuous monitoring of digital progress are crucial for the DT success (Bughin et al., 2019). Some industries have previously succumbed to DT, while for some industries DT represents a new challenge that has yet to face. According to the literature review results, the following goals for future work are set: (1) to determine whether AS possesses knowledge and skills to apply DT, using a digital maturity model, and (2) to assess the readiness of AS clients to apply DT concepts. Accordingly, the following research questions (RQ) are defined: RQ1: Do AS recognize the opportunities brought by digital transformation? RQ2: Do AS introduce new business models and restructure businesses in order to approach the digital transformation? RQ3: What challenges and barriers have been identified within AS that prevent them from carrying out digital transformation? RQ4: Are AS clients ready to improve their processes through DT?

2 LITERATURE REVIEW

AS will need to design systems for improved document analysis (Rehm, 2018) and less time consumption (Burritt & Christ, 2016). Cloud accounting (Diller et al., 2020; Supardianto et al., 2019) enables flexibility, synchronization and data availability. DT of AS includes machine learning (Sellhorn, 2020), artificial intelligence (AI) (Mosteanu & Faccia, 2020) and digital apps in auditing and report generation (Marshall & Lambert, 2018). Studies (Pihir, 2019) represent possible models of AS transformation – cloud AS (online accounting software provides insight into the data and facilitates clients – AS communication) and complete DT of AS (client with the help of AI use online software while AS has advisory and controller role over data entered by the client). Obviously, accounting skills will need to focus more on informatization (Sordi Schiavi et al., 2020).

3 METHODOLOGY

The logical research matrix is shown in Tab. 1. Each research question is related to the defined goal of the research, and hypotheses are defined in accordance with them. In addition, for each research question, research methods and scientific contributions are defined.

Tab. 1 – Logical research matrix. Source: own research

RQ	Goal	Hypothesis	Methods	Scientific contribution
RQ1 / RQ2 / RQ3	Measuring digital capabilities of accounting services in order to define their digital maturity.	(i) The level of maturity of AS in the transformation is at the level of I to II. (ii) Challenges and barriers present difficulties to DT and affect the low digital performance of AS.	Digital Maturity Model; interview; questionnaire; focus groups; self-assessment of accounting services; content analysis.	Define maturity of AS in DT project. Create a metamodel that includes DT concepts into new business models within AS. Systematization of difficulties related to DT.
RQ4	Assessment of the readiness of AS clients to apply DT in their own processes.	AS clients have a certain aversion to change the established way they work.	Interview; questionnaire; self-assessment of AS clients.	Create a metamodel that includes DT concepts into new business models within AS and clients.

4 RESULTS

Based on the literature review and the identified scope for future research, a logical research matrix (Tab. 1) was created with the purpose of reviewing the capacity of AS in digital transformation. Due to the achievement of the first research goal Measuring the digital capabilities of accounting services in order to define their digital maturity, different models of digital maturity will be considered and adapted to the scientific research context, with the possibility of creating own maturity model focused on AS. The structured interview will be conducted using a survey (on a target population and a selected sample for the survey - AS in Croatia), where the validity of the survey questionnaire will be previously examined by factor analysis. An unstructured interview, using several focus groups, will enable faster examination of research issues and immediate interaction with selected respondents. Also, AS will conduct a self-assessment of digital maturity based on a selected or independently created model of maturity, while the content analysis will identify challenges that hinder AS in digital transformation. The second research goal Assessment of the readiness of AS clients to apply DT in their own processes will include interviews with AS, but also IT organizations that support and collaborate with AS in implementing DT. By self-assessment of accounting services, the readiness to implement DT concepts in AS business processes will be assessed. Based on defined research goals (i) the maturity of AS in conducting DT will be defined; (ii) difficulties related to DT in accounting will be identified; and (iii) a metamodel will be created that incorporates DT concepts into new business models within AS and clients.

5 DISCUSSION & CONCLUSION

Accounting services represent a large but still untapped potential for change. They are lagging behind with the implementation of the DT project where DT offers them many advanced business opportunities, and it is up to them to take advantage of those opportunities in a timely manner. Difficulties prevent AS from transforming initiatives. Future research idea seeks to identify difficulties, but also wants to create recommendations for overcoming them. Creating AS digital maturity model would enable an overview of the current situation, but also defining possible improvements for progress and creating new business metamodels within accounting services that would represent the path to successful transformations. By engaging all

employees, clients, fostering an innovative and digital culture, strategically thinking about DT, the aversion to change will be removed, and AS will work to provide each client with personalized service. Although DT of accounting services is in their infancy, there are many benefits that organizations can get from the same - less time spent processing business operations, constant data availability, greater business transparency, improved business control, secure, reliable and personalized services, etc. All these benefits should be seen as a strategic advantage that AS and clients will achieve through self-initiative in terms of introducing DT in their businesses.

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USING CONVOLUTIONAL NEURAL NETWORKS IN STUDY OF PERIODIC SIGNALS IN NOVAE

Jozef Magdolen

Abstract

Nova systems can report during observation some variability. Such variability may be examined by displaying signal into frequency domain representation using a mathematical transform, e.g., Fourier transform or Lomb-Scargle algorithm. In this work we want to show, that using a standard periodogram for variability analysis may lead to confusion and ambiguity.

Keywords: *nova systems, periodic signals, signal analysis, signal variability, convolutional neural networks (CNN)*

1 INTRODUCTION

A binary system usually reports some variability during observation, caused by double nature; (a) the actual change in luminosity, and (b) the apparent change in luminosity (changes in light that can reach detector). Both, the intrinsic changes in luminosity and/or occultations are presented in nova outburst that are the origin of periodic and quasi-periodic signals, in which we are interested.

By creating a light curve of such nova and periodogram afterwards, we can determine the significance of certain frequencies in signal, its nature and the character of detected variability that can be stable or variable. The question, whether it is possible to distinguish between signal modulated by variable frequency with constant amplitude, and constant frequency with variable amplitude at all, constitute the basis of our research.

Using Monte Carlo simulations for nova light curves with different variability properties, creating theoretical time-maps (dynamic power spectra) and using a machine learning algorithm we will try to answer the asked question. Besides that, we will show, that even a signal modulated with both constant components (amplitude and frequency) can report behavior typical for variable frequency.

2 THEORETICAL BACKGROUND

The presence of ”doublepeak” in periodogram has long been taken as the evidence of multiple frequencies. To the same conclusion (that the period is not constant in time) came (Ness at al., 2015, p. 8-11) too by studying periodograms and time-maps of novae Kt Eri and Cal 83. They postulated, that the signal is affected by two close frequencies around 35 seconds for Kt Eri, and by variable frequency around 67 seconds for Cal 83 respectively.

However, Dobrotka and Ness (2017) showed, that such pattern may be modulated by one stable frequency and variable amplitude as well. They utilized direct simulations to demonstrate the effect of a variable amplitude on resulting power spectra. Based on this result is obvious, that these are two indistinguishable interpretations.

3 METHODOLOGY

To find out, whether it is possible to distinguish between different types of signal variability and whether even a signal with constant amplitude and constant frequency can report some

typical variability signs, we simulated thousands of different light curves based on nova systems Kt Eri and Cal 83 examined in (Ness at al., 2015).

Both systems were presented as most likely variable in frequency only. We created periodograms using Lomb-Scargle algorithm (used mainly for not equidistant sampled data) and time-maps of simulated light curves subsequently which reflects, how signal changes over time (during observation).

These time-maps were used as input to the CNN build on AlexNet architecture. The trained CNN on observed systems may find some hidden specific features in time-maps for every type of variability and estimate the confidence of such classification.

4 RESULTS

CNN trained on simulated time-maps based on nova Kt Eri showed accuracy only 47%, what can not be taken as a good result. However, the CNN trained on time-maps based on nova Cal 83 yielded more than 92% accuracy. Using such trained CNNs on observed nova systems, we got following results:

- Kt Eri:
  - 0.01% constant amplitude and frequency
  - 0.01% variable amplitude and constant frequency
  - 51.07% constant amplitude and variable frequency
  - 48.91% variable amplitude and frequency
- Cal 83:
  - 0.00% constant amplitude and frequency
  - 0.03% variable amplitude and constant frequency
  - 0.00% constant amplitude and constant frequency
  - 99.97% variable amplitude and frequency

More importantly, during the simulation process we found out, that even a signal with constant amplitude and constant frequency can report signs of variability typical for variable frequency, as shown in Fig. 1.

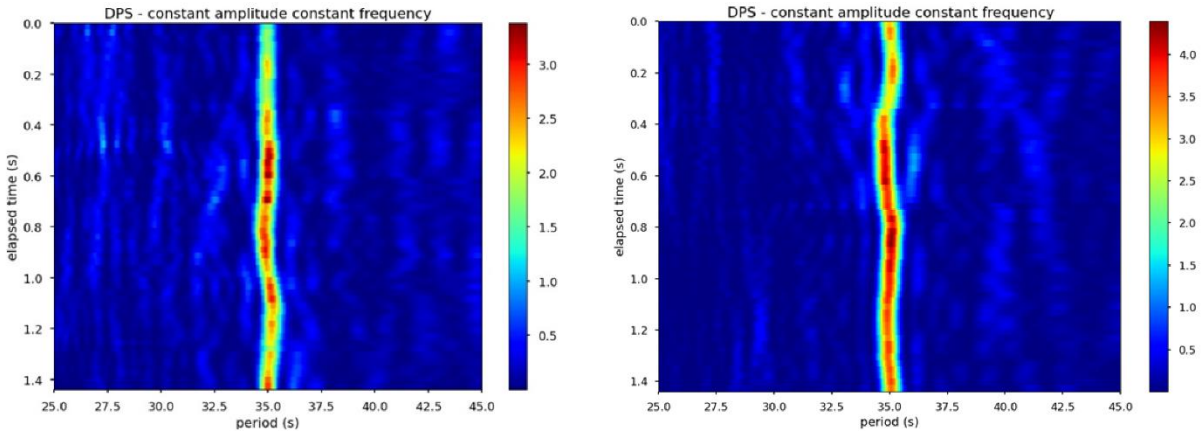

Fig. 1 – Signal modulated with constant amplitude and frequency in the left reports signs of variability in frequency as signal with variable frequency in the right. Source: own research

5 DISCUSSION & CONCLUSION

The goal of our work was to find out, whether it is possible to distinguish between a signal modulated by constant amplitude with variable frequency, and a signal modulated by variable amplitude with constant frequency.

The results of trained CNN shows, that both nova systems could be label as systems with variable frequency and variable amplitude in contrast to only variable in frequency reported by (Ness at al., 2015). However, we encountered a problem with very different CNN accuracy. Such difference is very confusing, since we used the same technique of simulation, and CNN architecture for both systems. Therefore, in-depth data analysis will be needed.

During light curves simulations we identified some time-maps, where the variability was clearly visible, but the signal was modulated with constant amplitude and constant frequency. Such finding was extremely surprising, and in the next research we will focus on this phenomena.

If there is no way to discern between periodograms created from signal modulated with constant components, and signal modulated with variable frequency, the result of such finding will have massive impact on the astrophysical community, where the signal variability is automatically linked to changes in frequency.

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USING VALUE PROPOSITIONS AS OPPORTUNITIES FOR IMPLEMENTING SUSTAINABILITY STRATEGIES

Adwoa Yeboaa Owusu Yeboah

Abstract

The work discusses practical and theoretical ways by which businesses can implement sustainability. By using the literature review methodology, it is argued that firms can design sustainable value propositions by using three main strategies namely: stakeholder involvement, implementing flexible decision models and emphasizing social and economic goals. The work finally discusses the benefits and challenges associated with the strategies.

Keywords: *sustainable value propositions, sustainability, shareholder involvement, flexible decision models*

1 INTRODUCTION

Even though studies on value propositions started several decades ago and have been analysed from several perspectives, the author argues that researchers should expand on the subject because of current demands. For example, contemporary works have explored value propositions in the light of sustainability, yet, because in such studies, the focus is usually on business models and the entire value creation model (Payne et al., 2017; Osterwalder et al., 2014; Frow & Payne, 2011), minimal attention is given to how value proposition can contribute to firm's sustainability performance. The author believes that this provides a general view of how it impacts sustainability (if any). Additionally, considering that each of the activities in value creation has implications for firm resources, they must be studied individually to adjust their resource allocation to reflect how they affect firms' sustainability performance. The current research aims to contribute to the literature on how firms can include sustainability into their value propositions, thereby contributing to their sustainability performance. To do this, the current work will (1) discuss three broad strategies that can assist business organizations in incorporating sustainable value propositions into their activities; (2) explain how incorporating these strategies can benefit the organization; and (3) identify challenges that firms are likely to encounter when implementing the strategy.

2 THEORETICAL BACKGROUND

Value propositions provides excellent opportunities to contribute to sustainability (Patala et al., 2016). By means of them, firms can provide sustainable offerings to their markets. But to achieve this, it is vital that they do the following: Involve stakeholders so that they can readily accept and support the firms' sustainability goals through co-creation (Owusu Yeboah et al., 2020; Ranjan & Read, 2016). Implement flexible decision-making models to ensure that firms provide alternative sustainable options when making decisions. With these options available, they will be more inclined to implement sustainability goals. Finally, they should emphasize social and environmental goals to promote sustainability. When firms encourage these, they can incorporate them into their value propositions (Manninen et al., 2018).

3 METHODOLOGY

The study is a qualitative study and hence, adopted the literature review method. The researcher, collected related literature from the Scopus, WoS and Google Scholar data bases. A total of 35 papers were suitable for the study. The keywords for the literature search are: sustainability, economic sustainability, social sustainability, environmental sustainability, shareholder involvement, shareholder engagement, decision making models and flexible decision-making models. From the literature possible linkages among the variables of the work were made. Based on the arguments in the papers, the author made conceptual arguments from the literature and suggests a conceptual framework.

4 RESULTS

The findings of the work suggests that firms can support sustainability by developing sustainable value propositions (Gilles & Christine, 2016; Müller, 2012). However, to achieve that goal they should work with both external and internal stakeholders (Horisch et al., 2014). They should also implement flexible decision-making models by creating a sustainable option for all their decisions. It was also identified that firms should explore social and environmental goals in addition to their economic goals so that they can better create value (Xu & Hu, 2020). The framework shows that each of these strategies can contribute to developing sustainable value propositions.

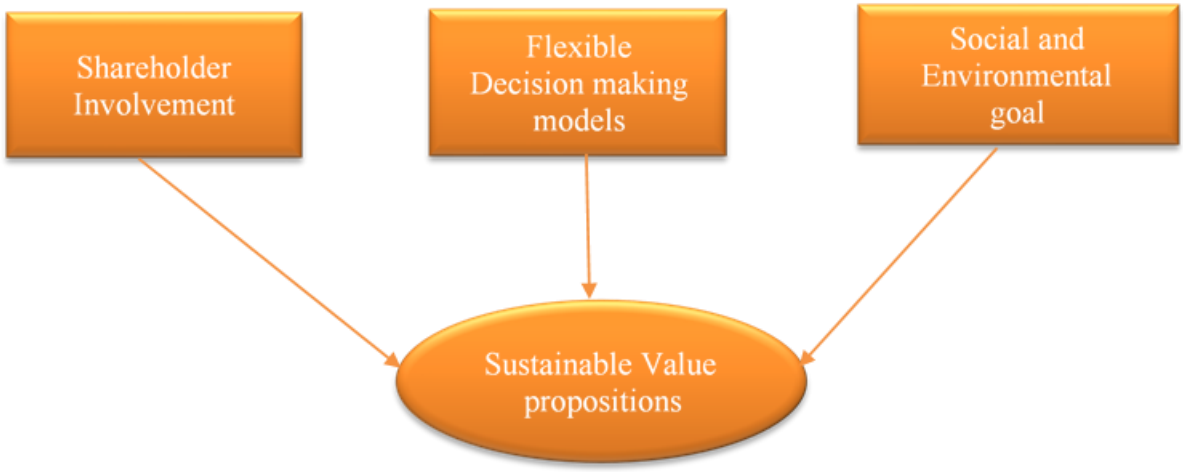

Fig. 1 – Sustainable Value Propositions. Source: own research

5 DISCUSSION & CONCLUSION

Benefits: These goals will enable business owners to achieve their sustainability goals and contribute to global sustainability. This will enhance their innovativeness since focusing on sustainability will require that they develop new ways of conducting their business operations. They may realize some of the business cases for sustainability such as cost reduction, risk minimization, attractiveness as employer, increased profits, reputation and brand value (Schaltegger et al., 2012). There is also the possibility of acquiring resources externally because of the firm's contributions to sustainability.

Challenges: Employees may resist these strategies. Business owners may not be willing to accept the initial cost associated sustainability strategies. Businesses may lack the resources needed for implementing these strategies.

Conclusions: The work suggests a conceptual model that shows three strategies that can contribute to developing sustainable value propositions.

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INTERREG V-A SLOVENSKÁ REPUBLIKA ČESKÁ REPUBLIKA SK-CZ 14-20

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BÍLÉ - BIELE KARPATY

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ASSESSING MANAGERS' INTENTION TO INVEST IN INTANGIBLE ASSETS IN SMES: THE EFFECT OF TECHNOLOGY ANXIETY

Diego Fernando Plata Lerma

Abstract

The purpose of this research is to examine the significance of technology anxiety (TA) within the Unified Theory of Acceptance and Use of Technology (UTAUT) framework by determining the intangible assets adoption intentions among Colombian SMEs. Intangible assets investments are characterised by comparably high inherent risk - particularly computerized information - consequently, owners-managers' feelings may be particularly affected in the decision-making process. Despite many attempts to extent the response power of the UTAUT framework, the affective components influencing SMEs' intention to adopt intangible assets remain unexplored, especially in emerging markets. The present study aims to fulfil this gap by including the technology anxiety construct interacting with performance expectancy (PE), effort expectancy (EE), facilitating conditions (FC) and social influence (SI), and considering age and revenue as control variables of the behavioural intention. Structural Equation Model by Partial Least Squares (PLS) path modelling was used to analyse and validate the proposed model. Considering the extant evidence corroborating the intangible assets' contribution to firms' competitive advantage, the results of this research are useful for governments and information technology consultants to design and execute appropriate strategies to encourage SMEs managers to include these technology-based innovations in their businesses.

Keywords: *Intangible assets, UTAUT, technology anxiety, emerging market*

1 INTRODUCTION

The current turbulent and innovative market dynamics have compelled firms to rely on intangible assets (IA) in order to improve its technological capacity and remain competitive. Intangible assets - the stock of non-financial assets without physical substance capable of being owned or controlled for use in commercial activities - are becoming a fundamental source of long-term market value. This research focusses on computerized information intangible assets considering the critical role that information technology (IT) plays in emerging markets SMEs.

While past research has focused on intangible assets' impact on performance (Chung, 2021), sustainable growth (Thum-Thysen et al., 2019) and productivity (Arrighetti et al., 2014) the study of the determinants of SMEs managers' intention to adopt intangible resources is still in its fledging stage. Despite being proved to play a determinant role in SMEs' technology adoption intentions (Camilleri, 2018), the affective variables are widely underrepresented in the extant literature, particularly in emerging markets.

This investigation proposes a theoretical model to address this gap highlighting the key role intangible assets play in generating competitive advantage in the current digital era..

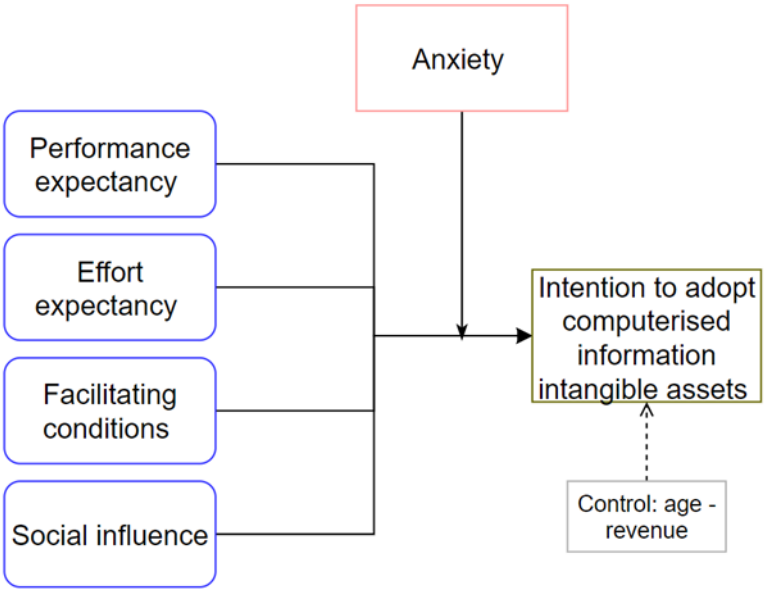

Fig. 1 – Research model. Source: own research

2 LITERATURE REVIEW

Tab. 1 – Relevant scientific articles on intangible assets investment. Source: own research

Author	**Key research highlight**	**Theoretical background**	**Research method**	**Unit of analysis**	**Country of study**
Arrighetti et al. (2014)	This research focused on analysing the firm's propensity to invest in intangible assets. The propensity to invest in intangible assets increases with the firm's size, human capital, and historical intangible asset base can be explained by factors that are internal and specific to the firm.	Capability-based theory	Quantitative	Organization	Italy
Camilleri (2018)	This study seeks to analyse the SME owner-managers' attitudes towards the innovation adoption and it examines their perceived use and ease of digital media for stakeholder engagement.	Technology Adoption Model (TAM)	Quantitative	Organization – owner, manager	Europe
Chung (2021)	This investigation examines the resource-based view of the firm's investment in intangible assets. It aims to study firm-level determinants of investment in intangible assets.	Tobit Panel Model	Quantitative	Organization	Korea
Thum-Thysen et al. (2019)	This study explores the determinants of investment in intangible assets and the differences with tangible assets. Macroeconomic conditions, regulatory framework, financial conditions and human capital were found to be determinants of investment.	Regulatory framework	Quantitative	Organization	Europe

3 METHODOLOGY

In order to operationalize the constructs stablished in this study, the anxiety-digitalized environment scale was adapted from Saadé and Kira (2007), the UTAUT variables from Venkatesh et al. (2003) and the SMEs' age and revenue are proposed as control variables. The data collection method is the cross-sectional survey and the statistical analysis method chosen for this study is Partial Least Squares (PLS). The sampling frame of this research include only SMEs' managers located in Colombian urban areas. Thus, the proposed hypotheses are:

H1: PE positively influences the intention to adopt computerised information IA in Colombia.

H2: EE negatively influences the intention to adopt computerised information IA in Colombia.

H3: FC positively influences the intention to adopt computerised information IA in Colombia.

H4: SI positively influences the intention to adopt computerised information IA in Colombia.

H5: Technology anxiety moderates the influence of (a) performance expectancy, (b) effort expectancy, (c) facilitating conditions and (d) social influence in the intention to adopt computerised intangible assets in Colombia.

4 RESULTS

The outcomes of the quantitative analysis potentially reveal the effect of technology anxiety on intangible assets adoption intentions in Colombia. The reliability of the technology anxiety construct in the model is verified with the Cronbach Alpha score and it is expected that the overall structural model accounts for more than 50% of the variance in the intention to adopt intangible assets among SMEs. Furthermore, the estimation is that, consistent with previous research, the results confirm the significance of technology anxiety in moderation analyses (Saadé & Kira, 2007). In fact, it is expected that anxiety influences negatively performance expectancy (most determinant construct) and effort expectancy in the intentions to adopt intangible assets. This implies that managers who have the intention to adopt intangible assets, decide not to do it due to anxiety behaviours. On the other hand, the results regarding the facilitating conditions and social influences are expected to be not straight forwarded after the revenue and age control effect, revealing mixed outcomes.

5 DISCUSSION & CONCLUSION

A plethora of previous studies have showed that high levels of anxiety will negatively influence the intention to adopt a new technology (Yang & Forney, 2013; Lee, 2011), however, these investigations have tended to focus in user/customer adoption prediction and organizations' innovation investment drivers are unexplored, especially individual affective components. According to Gunasinghe and Nanayakkara (2021) the analysis of emotions such as anxiety in technology behaviour intentions, particularly in an emerging market context, is extremely relevant. The model presented in this investigation aims to provide richer explanatory and predictive insights into the SMEs' behavioural intentions to invest in intangible assets by integrating an affective component into the UTAUT framework expecting to alter its relationships while enhancing generalizability. This study provides several practical and theoretical implications, especially as the role of emotions in SMEs intangible assets investment intentions has been widely understudied.

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ALLOY LAYER FORMATION ON CARBON STEEL SUBSTRATE DURING HOT-DIP GALVANISING

Henrich Suchánek

Abstract

The aim of the current study was to obtain knowledge about the most suitable method of galvanising of low and high carbon steel substrates and advise them for use in industrial production. The experimental part deals with the investigation of microstructure, especially the alloy layer formed at different zinc bath temperatures and immersion times in the zinc bath during the galvanising process.

Keywords: *Hot-dip galvanising, pure zinc bath, alloy layer thickness, steel substrate*

1 INTRODUCTION

Hot-dip galvanising (HDG) is a widespread process. Many resources are oriented on HDG including pure zinc baths, or with the addition of alloying elements. However, these are mainly focused on low carbon steel substrates (Bakhtiari et al., 2014; Bicao et al., 2008; Dallin, 2015; Hakim et al., 2018; Kuklík & Kudláček, 2016; Marder, 2000; Okafor et al., 2013; Shibli et al., 2015). On the other hand, continuous HDG of wires in most cases uses medium and high carbon (>0.5 wt.% C) steel substrates. HDG in these cases is performed often in a bath consisting of pure Zn because it has several advantages for the final applications in specific corrosion environments. Nevertheless, there is still limited availability of adequate resources, which discuss the issues of pure Zn coatings on high carbon steel substrates.

The main goal of the present work is to modify the process parameters of HDG of high-carbon steel substrates so that the process is accelerated while improving the drawing ability of galvanised wires without negatively affecting the performance of the product. Due to these considerations, it was decided to study the formation of intermetallic layers at different HDG temperatures, immersion times and on substrates which differs in carbon content. The result of these experiments should therefore be a set of findings that will lead to the conclusion of whether it is possible to accelerate the HDG process by changing process parameters, improve the ductility of high carbon high strength wires in the drawing process and maintain excellent corrosion resistant properties of the product.

2 LITERATURE REVIEW

Various authors agree that steel with content up to 0.2 wt. %, in some cases up to 0.3 wt. % has no or rather very low influence on reaction kinetics between solid substrate and liquid zinc (Kuklík & Kudláček, 2016; Guttmann, 1994). However, increased carbon content (>0,3 wt.%) can increase the reaction rate of dissolution of iron in the melt and therefore, disproportionately increase the overall coating thickness of phase zeta (ζ). Higher carbon content (0.8-1wt.% C) supports growth both delta and zeta phase, whereas growth of zeta phase is more significant (Smirnov, 1956). Kopyciński et al. (2017) and Szczęsny et al. (2017) where galvanised substrate was cast iron containing more than 3 wt.% C. Results of this studies declare differences in alloy layer morphology as well as alloy layer thickness of high carbon galvanised substrate compared to low carbon galvanised substrate. Overall alloy coating thickness as a function of zinc bath temperature and immersing time is investigated by Al-Shamry and Mahdi

(2018). In conclusions of this study, higher immersion times increasing alloy layer thickness when hot-dip galvanising is performed at temperature from 450 to 550°C.

3 METHODOLOGY

Before galvanising, the steel substrates were cleaned by pickling in 20 vol.% aqueous solution of HCl acid followed by wiping and dipping in an aqueous solution of "double-salt" flux (ZnCl2.2NH4Cl) with subsequent removal from flux bath and air drying. Hot-dipping was performed at 520°C and immersion times were ranging from 5 to 300 s. Temperature of the melt was constantly monitored by a K-type thermocouple inserted directly into the melt. Quantitative metallographic analysis including thickness measurements of coexisting phases was performed by computerised image analysis using ImageJ 1.52. Only the alloy layer thickness was investigated. Thickness of the η (pure zinc) layer was not investigated because thickness of this layer is not controlled by diffusion (as in case of intermetallic phases Γ, δ and ζ), but rather by dynamic forces acting on molten dipping alloy when the coated steel substrate is pulled out from the Zn bath in a vertical direction.

4 RESULTS

Only the total alloy layer thickness was investigated (Fig. 1). It is clear that with increasing immersion time the total alloy layer thickness has increasing tendency. Characteristics of Fe-Zn intermetallic compounds are shown in Table 1.

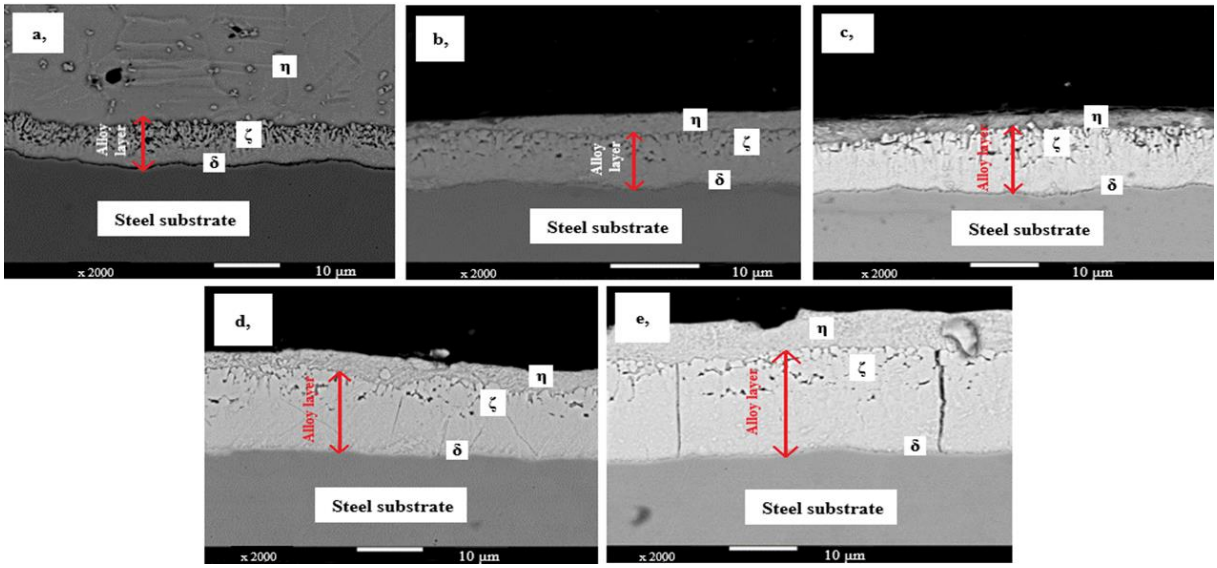

Fig. 1 – Cross section of samples produced at 520 °C: a) 5 s; b) 15 s; c) 30 s; d) 60 s; e) 300s. Source: own research

Tab. 1 – Characteristics of the Fe-Zn intermetallic compounds. Source: Bicao et al. (2008)

Layer	Iron [wt.%]	Crystal structure	Alloy characteristics
Eta (η)	0.03	Hexagonal	Soft, ductile
Zeta (ζ)	5.7 – 6.3	Monoclinic	Hard, brittle
Delta (δ)	7.11	Hexagonal	Ductile
Gamma (Γ)	20 – 27	Cubic	Hard, brittle
Steel base	99+	Cubic	---

Thickness of the η (pure zinc) layer was not investigated because thickness of this layer is not controlled by diffusion (as in case of intermetallic phases Γ, δ and ζ), but rather by dynamic

forces acting on molten dipping alloy when the coated steel substrate is pulled out from the Zn bath in a vertical direction. The output of the thickness measurement (Fig. 2 & 3) of the alloy layer is exponent value, supported by power law of growth (Eq. 1 & 2), which show us what controls the growth of total alloy layer (Yao et al., 2016). In our case the growth evolution is governed by volume diffusion.

$$x = At^n\left(\frac{-Q}{RT}\right) = kt^n \tag{1}$$

$$\mathrm{n} = \log(x - x_0)\ \text{vs.}\ \log(t - t_0) \tag{2}$$

n = 1 (chemical reaction)

n = 0.5 (volume diffusion)

n = 0.33 (grain boundary)

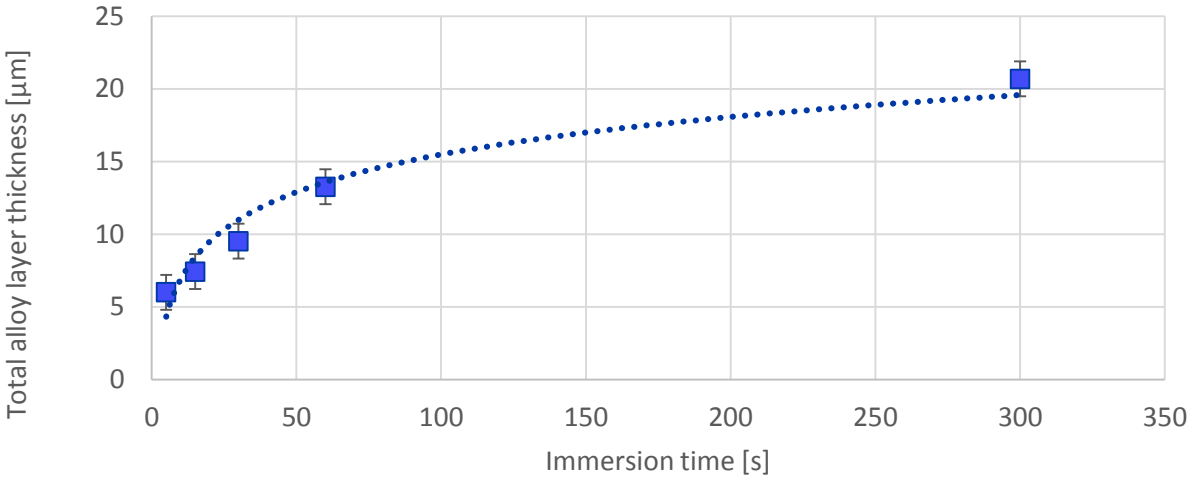

Fig. 2 – Total alloy layer thickness vs immersion time. Source: own research

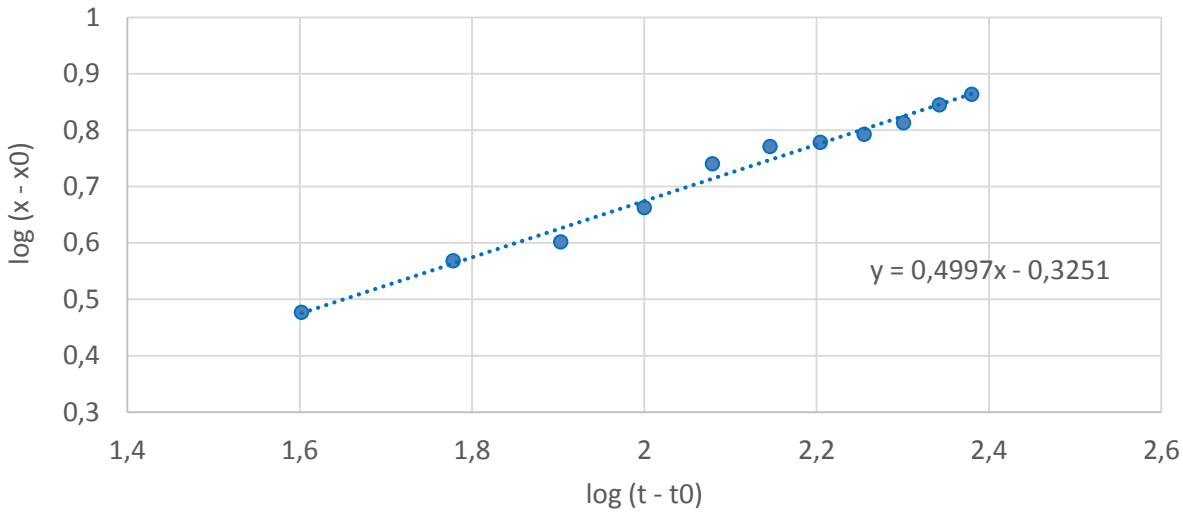

Fig. 3 – The thickness vs time increments for the total alloy layer (logarithmic scale). Source: own research

5 DISCUSSION & CONCLUSION

To expand knowledge about the HDG process with focusing on changes in the phase composition of Fe-Zn alloy layer, substrates with different carbon content should be evaluated. Studied galvanised microstructures of carbon steels (0.5 wt.%C) are similar to results of Bicao et al. (2008) and Bakhtiari et al. (2014). Thickness measurements of total alloy layer are also approximately the same if the thickness at same immersion time and temperature is compared, which means for example at galvanising condition (520°C, 60 s) the total alloy layer thickness is slightly about 13 μm. On the other hand, compared to the galvanised high-carbon steel substrate (in our previous study), the microstructure and the total alloy layer thickness differs, but this can be caused by different galvanising temperature used in each study (Gogola et al., 2020). Only the trend of increasing alloy layer thickness with increasing immersion time is the same in each case. To sum up, increasing dipping time from 5 to 300 s increases the alloy layer thickness. Also, would be beneficial to study performance of alloy layer at a wider interval of galvanising temperatures, to perform wrapping tests and corrosion tests which would give important information for further technological processing as well as suitability for application in corrosive environments.

5.1 Future ideas

To secure optimal HDG conditions it would be beneficial to compare microstructures (individual and total alloy layer thickness) with microstructures prepared at different HDG conditions as well as different carbon content (0.7 and 0.9 wt.%) of substrates.

Qualitative analysis of individual phases galvanised at 520°C by XRD and EBSD.

Estimation of suitability for further technological processing (drawing) by applying the wrapping test.

Corrosion testing (salt spray test – SST or stress corrosion cracking – SCC) to identify which coating is the most resistant against corrosion even with a tensile stress imposed on tested samples.

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POLYMER BLENDS CONTAINING POLYBUTHYLENETEREPHTALATE (PBT) REACTIVE BLENDING

Soňa Zenzingerová

Abstract

This work deals with the process of creating the blend from polyolefin polypropylene (PP) and thermoplastic polyester PBT. Due to the immiscibility of these polymers, polypropylene grafted with maleic anhydride is used in the concentration of 2 wt. %, ensuring by in situ reaction compatibilization of the blend. Polymer blends containing polypropylene and polybutylene terephtalate were prepared by the process of reactive blending. The process of compatibilization positively affects miscibility of immiscible polymers; the substance is known for creating a more stable and better-blended morphology of phases by creating interactions between two immiscible polymers. Mechanical, chemical and heat properties of the blend should be enhanced. A well-formed polymer blend exhibits combined properties of the starting components. The effect of the compatibilization on the morphology of the blends by SEM and FTIR analysis was evaluated. The effect of the compatibilization on mechanical and melt-flow properties was evaluated. The effect of the different content of maleic anhydride, grafted on polypropylene, on the properties of the blends was evaluated.

Keywords: *polypropylene, polybutylene terephtalate, maleic anhydride, polymer blends, reactive blending, compatibilization*

1 INTRODUCTION

When creating the polymer blend, the main issue is that polymers are often immiscible which negatively affects the quality of created blend. Thus, the mixing process requires to be assisted by the addition of a substance reducing the interfacial tension and ensures good dispersion of the blend components (Baker et al., 2001; Paul & Barlow, 2007; Utracki, 1998).

This work deals with the process of creating the blend from polyolefin polypropylene (PP) and thermoplastic polyester PBT. Due to the immiscibility of these polymers, polypropylene grafted with maleic anhydride is used in the concentration of 2 wt. %, ensuring by *in situ* reaction compatibilization of the blend. PBT is mainly used in the automotive and electronic industry. The blend of PBT with polyolefins may be a suitable way to recycle PBT waste. The compatibilization should also work in the blending of PET with other polyolefin polymers, not only PP.

2 LITERATURE REVIEW

Many studies have shown, that the process of compatibilization positively affects miscibility of immiscible polymers, thus creating a more stable and better-blended morphology of phases by creating interactions between immiscible polymers (Baker et al., 2001; Paul & Barlow, 2007; Utracki, 1998). A well-formed polymer blend exhibits the combined properties of the starting components (Mantia et al., 2017) (PP/PET blends). The effect of higher rate of GMA in EGMA compatibilizator used for PP/PBT blends was also studied (Tsai & Chang, 1996).

PP is not compatible nor miscible with PBT due to differences in their polarity. Also, PP does not contain any functional groups with which it can react with PBT. The PP/PBT blend can be mixed by adding a polymer, miscible with PP and reactive with PBT.

In this work, used maleic anhydride grafted PP is polar and able to react with PBT hydroxyl groups to form a PP-MA-PBT copolymer, which works as a compatibilizer of the PP and PBT blend. Fig. 1 presents the reaction of PP - MA with PBT forming an intermolecular bond between carbonyl oxygen (δ–) of MA and hydrogen in the hydroxyl group of PBT (δ +). In Figure 2 a formation of copolymer between PP-MA and PBT is illustrated. A similar reaction chemism was shown in the study by (Kang et. al., 1997), where maleic anhydride-grafted ethylene-vinyl acetate (EVA-MA) was used instead of PP-MA.

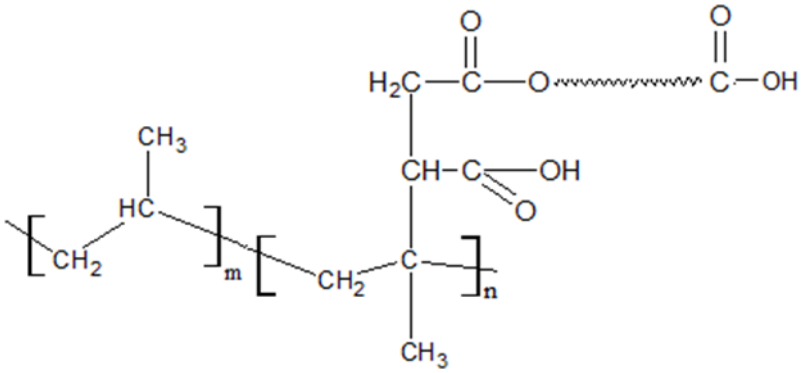

Fig. 1 – Formation of copolymer PP-MA/PBT. Source: own research

3 METHODOLOGY

PP C766 – 03 was obtained from Dow Chemicals, PBT Arnite T08 200 from DSM, PP – MA containing 1.30% of MA (known as Fusabond P353) and PP-MA containing 0.47% of MA (known as Fusabond P613) from DuPont.

The components were mixed and extruded into strings by using a LabtechEngineering screw extruder. Extruder temperatures were set from 220°C to 255°C, speed at 100 rpm. The strings were pulled into a water bath. Afterwards, the strings were granulated and the granules are placed in an oven at 80°C for 24 hours and then hot-pressed into the plates.

Tab. 1 – Prepared blends with weight percentage of individual elements. Source: own research

	PP/PBT	PP/PBT	PP/PBT	PP/PBT/PP-MA 1.3%	PP/PBT/PP-MA 0.47%
PP	100	0	70	70	70
PBT	0	100	30	30	30
PP-MA 1.3%	0	0	0	5	0
PP-MA 0.47%	0	0	0	0	5

Scanning electron microscopy (SEM) was used for evaluating the degree of phase-mixing. Morphology of the samples (plates) was examined by SEM VEGA LMU Tescan.

Elongation at break and tensile strength were tested on a Quasar 25 (Galdabini) according to standard EN ISO 527-1-3:1997 at a temperature of 23°C. The samples were pulled at speed 100mm/min at standard temperatures. The Shore D method was tested on the HHP 2001 hardness tester according to the ČSN EN ISO 868 standard at standard temperature. The melt flow index (MFR) was tested on the Plastometer SVIT device according to the standard EN ISO 1133.

4 RESULTS

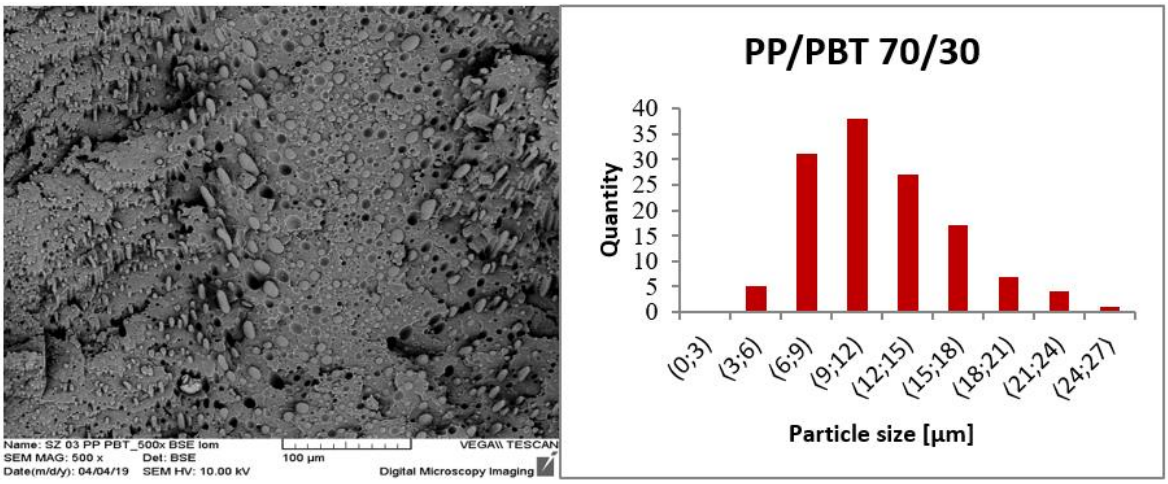

Fig. 2 – Particle sizes of PBT in PP matrix without compatibilization, obtained from SEM, average particle size 12±5 µm. Source: own research

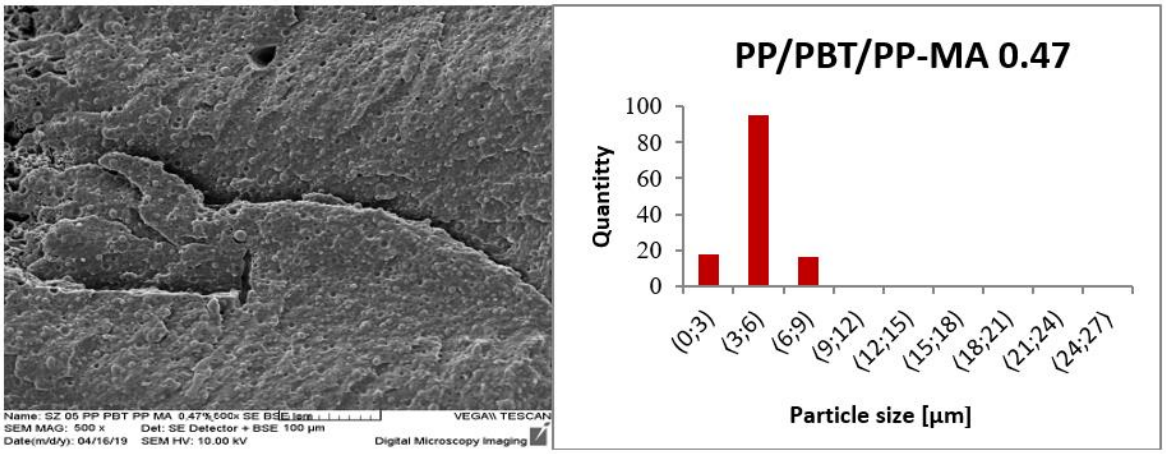

Fig. 3 – Particle sizes of PBT in PP matrix with compatibilization (PP-MA 0.47%), obtained from SEM, average particle size 4±2 µm. Source: own research

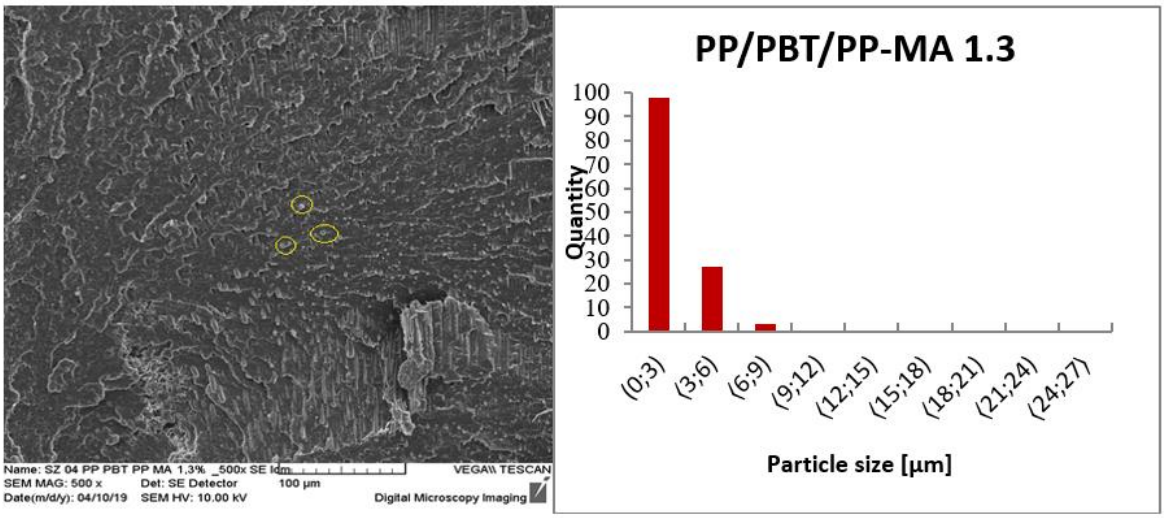

Fig. 4 – Particle sizes of PBT in PP matrix with compatibilization (PP-MA 1.3%), obtained from SEM, average particle size 2±1 µm. Source: own research

Tab. 2 – Mechanical properties of all samples. Source: own research

	E [MPa]	δmax [MPa]	εmax [MPa]
PP/PBT 100/0	1610 ± 50	24.8 ± 0.4	10.2 ± 0.2
PP/PBT 0/100	2230 ± 40	44.2 ± 0.7	3.2 ± 0.1
PP/PBT 70/30	850 ± 20	19.6 ± 1.3	5.8 ± 0.3
PP/PBT/PP-MA 0.47%	1060 ± 30	23.8 ± 0.9	4.0 ± 0.2
PP/PBT/PP-MA 1.3%	980 ± 30	15.4 ± 0.7	2.9 ± 0.2

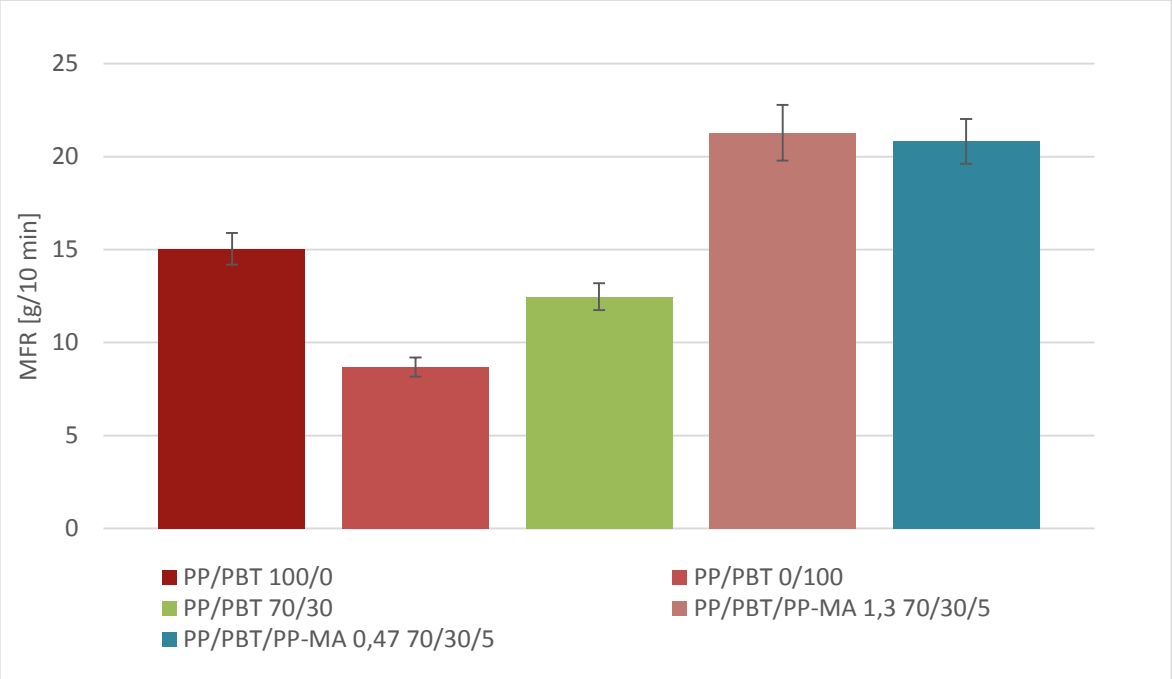

Fig. 5 – Melt flow rates of all samples. Source: own research

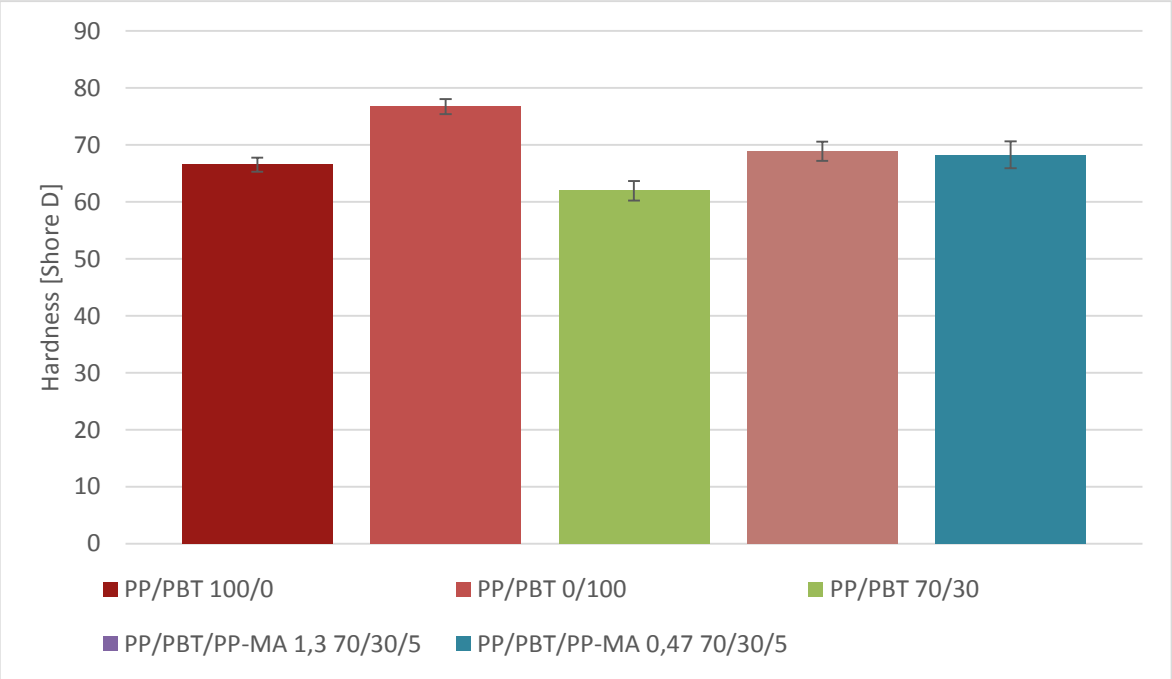

Fig. 6 – Hardness of all samples. Source: own research

5 DISCUSSION & CONCLUSION

According to the theoretical knowledge about the miscibility of polymers based on studies (Kratochvíl & Kelnar, 2015; Utracki,1998), PP-MA was used as a polymer which, during the reactive blending, forms a compatibilizer and modifies the miscibility of PP and PBT by forming a PP-MA-PBT copolymer. The copolymer thus formed is miscible with PP. The creation of copolymer and predicted chemism was confirmed by FTIR (see Fig. 1). The importance of using a compatibilizer was confirmed by SEM analysis (Fig. 2, Fig. 3, Fig. 4), where it was visible that the compatibilizer reduced the size of the PBT particles and improved their dispersion in the matrix. Due to compatibilization process of the blend components, hardness (Fig. 6) and tensile strength (Tab. 2) are reduced in the case of compatibilized mixtures compared to pure PBT. The compatibilized mixture has a higher MFR than pure components (Fig. 5). Thus, it can be said, that the process of compatibilization positively affects miscibility of immiscible polymers; the substance is known for creating a more stable and better-blended morphology of phases by creating interactions between two immiscible polymers. Mechanical, chemical and heat properties of the blend are enhanced. A well-formed polymer blend exhibits combined properties of the starting components.

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