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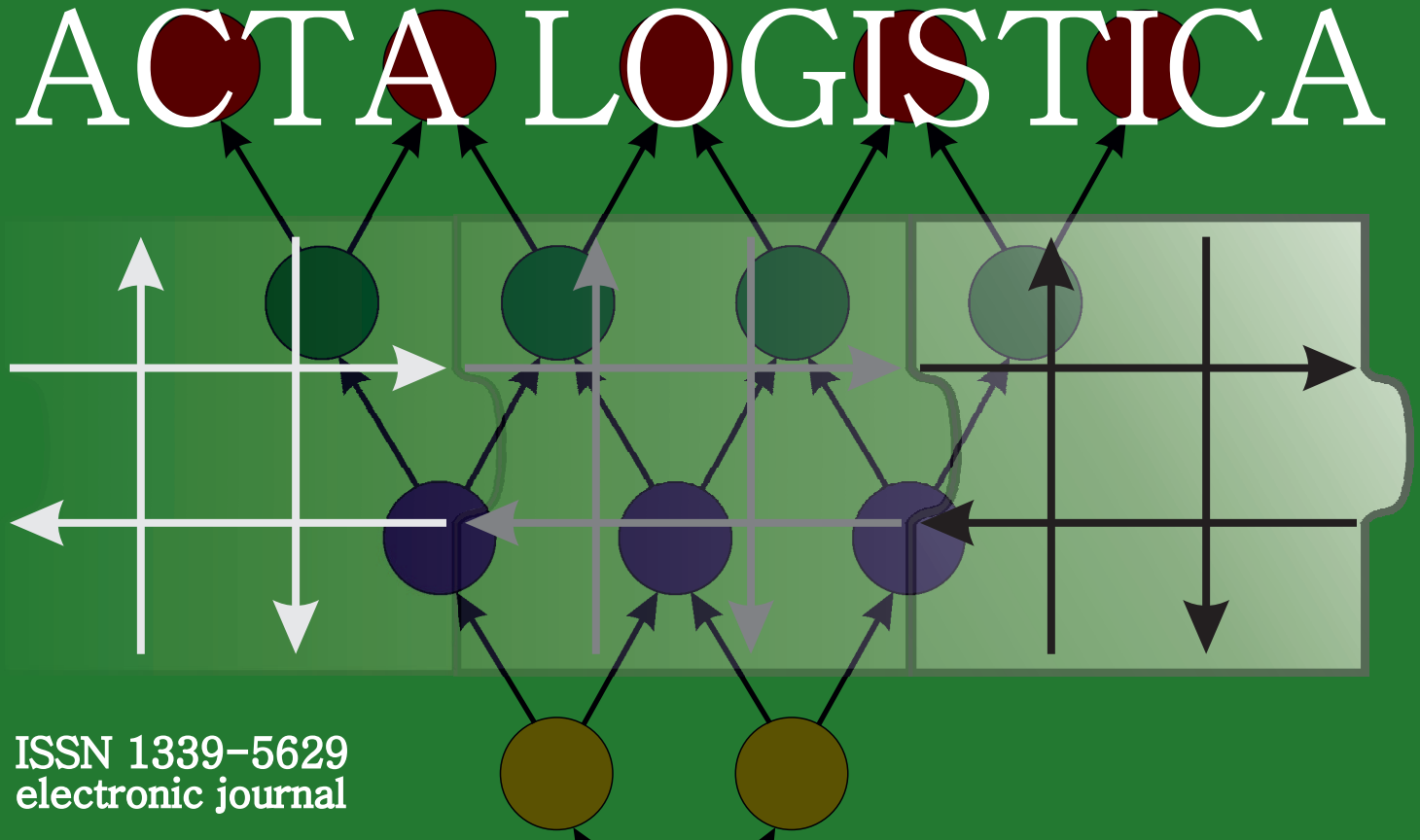

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PROPOSAL OF A MODEL FOR THE ECO-INNOVATION INTEGRATION INTO THE INNOVATION PROCESS OF COMPANIES IN SLOVAKIA TO INCREASE THEIR PERFORMANCE

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Abstract: The issue of innovations, as well as ecological innovations, is a concept in Slovakia, to which considerable attention is paid because they affect all spheres of society. They relate to production, logistics, sales, and the consumers, who decide on their acceptance on the market. However, the success of innovation in the market depends on several factors that influence the innovation process. They are not just determinants that act pro-innovation and thus support innovation and innovation process. In the innovation process, some factors have the opposite effect and result in forces that suppress the creation of innovation. Therefore, in this article, we focus on mapping the state of pros and cons of innovation forces acting on companies' innovation process in Slovakia. Based on the above findings, we have identified a large interest in implementing innovations, using an open innovation system to implement innovations and implementing eco-innovation. On the other hand, we have also identified negative factors influencing companies' innovation process such as lack of financial resources, high bureaucracy, lack of relevant information for creating innovations, low awareness of eco-innovation, etc. Subsequently, based on the findings, we proposed a model for eco-innovation integration into companies' innovation process in Slovakia, which was the paper's aim. The proposed model eliminates mainly the negative influencing factors of the innovation process in companies, and at the same time, it should support them for the innovation direction. Implementing the proposed model should lead to an innovation increase in companies, but their positive impact also applies to environmental support and an overall increase in the company´s efficiency in Slovakia.

1 Introduction

Innovation is considered an important tool to succeed in an environment characterized by strong competition in the market. It is important to manage the innovation process and its implementation and seek inventions, financial resources, and many other aspects that are the incentives for successful acceptation of innovation in the market when innovation is implemented. They present input in the innovation process as a source when beginning but also implementing the innovation. Internal as well as external sources reimburse the sources representing the innovation capacity of the company.

As it is presented by Straka et al. [1], distribution logistics provides the physical, organizational and information link between resources and the innovation process. It plays an important role in ensuring the most appropriate way to select, analyze, and transport these resources during the innovation process.

However, it is not sufficient just to innovate. The attention is focused when innovations are created and implemented on the principle of sustainable development, thus representing ecological innovation. The EU [2] states, it is important to implement ecological innovations that increase the protection of the environment and the competitiveness of EU industry. It should be realized by introducing technologies, processes, business models, and logistic system models that use resources more effectively [3,4].

Activities of logistics entities, creation of document flows, implementation of logistics operations and functions are influences by developing supply chains regulation methods in logistics, including the regulatory framework. It has a direct and indirect impact on them. Logistic activities are subject to existing laws and by-laws. Methods of centralized, unified regulation of logistics chains as a set of subjects, objects, and logistics activities are significant to promote material, information, financial, and other flows from the starting point to the destination. The logistic approach to economic processes managing is based on the operation of information standards, business and other regulatory acts in the field of logistics. Nowadays, all countries in the world have to comply with international and national laws and regulations. This task is currently the most urgent for all companies to timely react and meet all legislative and market requirements. They have to develop environmental programs and

collaborate with the government to improve the environmental guidelines and standards [5].

Companies' self-regulation of social and environmental impacts is promoted to solve the regulatory problems that developing countries solve. Since globalization brings many potential opportunities for businesses in developing countries, governments of developing countries consider the international legal norms to be helpful [6]. At the same time, it creates an important regulatory problem. In recent years, private companies have been under increasing pressure to take responsibility for social and environmental issues. The critical attitude towards private companies and their impact on society dominates. To solve this ambiguity, integrating social responsibility into governance processes is recommended. This can improve accountability, promote and guide corporate responsibility, provide companies with ways how to systematically develop innovation processes and environmental parameters. New economy approaches (such as the information economy and network economics, logistics) have provided new knowledge [7]. With changes in logistics management and a wide range of logistics tools and instruments, the environmental impact of the logistics system is becoming more serious with the increase in the volume of logistics. Logistics is now playing an important role in economic and social development because of the rapid growth of science and technology and the growth of the global economy. The development of logistics is also very essential for quality and efficiency improvements within the national economy, optimizing the distribution of resources, improving investment conditions, promoting industrial restructuring and increasing economic power, the importance for economic growth and increasing the employment potential, as well as the ecological situation of the country [5,8-10].

Logistics understands and deals with parts of the real world, such as logistics systems. The logistics system is a system that manages, secures, and implements logistics flows and chains. Its active elements are machines, equipment, people, activities, processes, and they realize the "movement" of passive elements materials such as products, information, money, people creating flows. There are other logistics systems around the logistics system because we perceive each object of the process as a logistics system. Logistics systems consist of a finite number of active elements forming the chains and networks in which logistics flows take place [11].

It is more advantageous from a cybernetic perspective to apply a feed-forward management system in these systems [12,13]. Their structure implies the use of several types of models. Through logistics models, we can simulate changes in the parameters of input variables, network models to determine the critical path in project management, simulation of production and distribution plan through public service systems, simulation models, Gantt diagrams showing the implementation of processes, etc. In general, it can be said that simulation is a method to find out the state or behaviour of a real system using a model. Simulation is a method in which we imitate (replace) a real system with its simulation model, on which we perform experiments. The results are retrospectively applied to the real system [11,14].

Logical and business models, as it is mentioned above, involve many aspects and incentives that affect economic processes and innovation. Moreover, the innovation incentives at all levels can differ. Therefore, this manuscript aims to monitor and propose an eco-innovation integration model applied to companies' innovation process in Slovakia aimed to increase their performance.

2 Methodology

The primary method of the survey is "Methodology of knowledge mapping industrial clusters" by Lodl [15], which consists of three basic steps:

The first step is the identification of key processes of companies or industry. Internal resources (organizational manuals or quality management system documentation) are used for this identification. In this step, it is necessary to get a picture of a recognized or established industry process system. Using the analytical-synthetic method, we analyzed the issue of innovations, ecological innovation, innovation process, financing, their support, innovation system and other contexts, focusing on the links between them.

The second step is identifying knowledge, where a survey is applied with people from the individual processes, only if they are experts in the field [16]. In this step of the methodology, the questioning of knowledge is carried out by means of a questionnaire consisting of questions concerning individual processes and the identification of knowledge about the researched issue - innovations, ecological innovation, innovation process, financing, their support, innovation system and other contexts. The online survey method is used to study the attitude of stakeholders [5]. The survey was carried out in electronic form and was attended by 327 companies from all over Slovakia.

After collecting the data, it is possible to move to the third step, namely the proposal of a knowledge map representing "The proposal of a model for the eco-innovation integration into the innovation process of companies in Slovakia in to increase their performance". It presents a logistic model of the system of planning, synchronization, management, implementation, and control of internal and external flows for the highest flexibility, accuracy, economy, and innovations support within the innovation system in Slovakia within the integration of ecological innovations into the innovation process of companies. The analytical-synthetic and inductive-deductive method were used when creating the model. They drowned basic logical procedures found by previous methods. Then they were proceeded in creating the model from general laws and facts towards individual

phenomena and relationships and from general principles to specific ones.

3 Result and discussion

To process the proposal of a model for the eco-innovation integration into the innovation process of companies in Slovakia to increase their performance, the first step had to be to identify key processes within the innovation process as the first step. Then as the follow-up step, there was identified knowledge on the implementation of ecological innovations and innovations into the innovation process within Slovak business entities.

Identifying key processes within the innovation process is based on the available literature on models of the innovation process because it is necessary to create a picture of a recognized or established system of processes of the researched issue - the innovation process.

Identifying key processes within the innovation process is to systematically influence the reproduction of business in accordance with the growing needs and requirements of the consumer and the market, considering 3 C (Customers, Competitions and Change). The synergy of innovation process management regarding market aspects increases the efficiency of investments in new processes and products [17,18].

Therefore, the most effective implementation of innovation processes must be analyzed in terms of its forms or models of use in the company, which can eliminate risks during its implementation in such a way that to meet the most important attributes.

Analysis of innovation processes shows that the first model used to implement innovations by organizations is a linear sequence of certain functional activities. We either talk about "technology-driven" innovations representing the opportunities that have emerged from research and development within the innovation process or "demand-driven" innovations. It means that the market signalized the need for something new, which subsequently led to an innovation process whose output is an innovation.

The linear model of the innovation process represents a complex system divided into three basic parts:

- creation of invention - impulse, idea, the proposal of a possible solution, which after assessment turns into an innovation opportunity and after processing results in innovation.
- creation of innovation - scientific, research and development, organizational or experimental activity, the aim of which is to start the innovation process or keep it at the necessary pace.
- penetration of innovation, diffusion of innovation on the market - expansion of new or already adopted and used innovation in new conditions, new markets, or new application places [19].

These parts, activities and phases express a complex view of the innovation process, which in the case of partial innovation changes is purposefully minimized only to those parts, phases, and activities necessary to ensure the innovation.

Also, the specific conditions in which the innovation process takes place may influence the participation or non-participation of a particular phase. Alternatively, they can lead to a reduction or, conversely, to an expansion of the content of any of them. In terms of time sequence, consistent placement and adherence to the individual phases in a row are practically unbearable. The need to accelerate the innovation process (for example, by exploiting the potential of current information technology and technique) makes it increasingly urgent to shorten each phase and ensure that the process is organized, allowing maximum overlap of the individual phases over time.

For these reasons, it is important to analyze innovation processes, which can take various forms, in addition to the already mentioned innovation process, in the form of a simple linear model, chain-linear model, nonlinear innovation model of open innovation, innovation process model by Tidd, Bessant and Pavitt, innovation models by Schumpeter, innovation model by Schmookler, innovation model by Rothwell, Klin's model of innovation, Beije's innovation model, model of the innovation process by business to customer and business to business. Models of the nonlinear innovation process represent an open approach to the innovation process, which facilitates the information penetration to support the creation of innovation within organizations but also countries, which is currently supported by innovative platforms of information and communication technologies stimulating innovation [20]. The output is an open innovation system, which is also open to other opportunities to innovate the business in the form of start-up or spin-off companies.

The second step is knowledge identification. In this step of the methodology, the inquiry of knowledge is realized. It consists of questions concerning individual processes and the identification of knowledge about the researched issue - the innovation process. Based on the survey, we came to the following findings in the implementation of the innovation process. 53.20% of the total number of addressed companies believed that the innovations implemented by them are ecological and 46.80% do not consider them ecological.

In implementing the innovation process, most companies (59.60%) also cooperated with other subjects. It means they use a nonlinear innovation process to implement innovations based on an open innovation system. Linear innovation process was used by 40.40% of companies that implemented the innovation process without the participation of other subjects. The key entities with which companies cooperated on innovations include suppliers (55.10%) and other subjects (25.80%). Cooperation with customers (10.70%) and the Ministry (5.80%) was less implemented. Only a few companies collaborated on innovations with business angels (1.30%) and clusters (1.30%). None of the companies cooperated on innovations with the Slovak Business Agency. They

also did not mention other institutions that would participate with them in the innovation process.

The factors that, in respondents´ opinion, negatively influence the development of innovations. Thus, eco-innovations include the company´s high costs associated with introducing innovations and the time-consuming return on investment. They also consider the high level of risk and, interestingly, the lack of professional and qualified human resources to be a crucial negative factor. The process that is associated with obtaining and implementing innovations in practice is quite lengthy. It is also perceived this way by the respondents of our survey, who identified bureaucracy as the next negative factor. They also negatively perceive the impact of a pandemic, which threatens the innovation process, so businesses cannot invest as much money in the innovation process as they would be if the pandemic did not occur. Also, in connection with subsidies at the time of the pandemic, they began to consider the black passenger effect as a problem.

Moreover, frequently changing pandemic, but also other measures and legislation are often unclear. Many companies are discouraged from introducing innovations by a lack of financial resources and insufficient experience and know-how in the company. Insufficient consumer readiness, on whom the acceptance of eco-innovation depends, and too traditionalist thinking among producers and a lack of knowledge on sustainability issues can be considered a significant problem. Respondents perceive the lack of information on the possibilities of financing innovations and subsequently other factors to be less significant negative factors.

Researched companies consider that these areas would contribute to the support of ecological as well as innovations as a whole:

- financial support from the state (stated by 12.50% of companies),
- less bureaucracy (10.30%),
- sufficient financial resources to implement innovation (9.40%),
- better information – e.g., easier access to obtain information on the possibilities of introducing innovations into practice (8.50%),
- more public awareness of eco-innovation and its importance (8.10%).

After collecting these data, it is possible to proceed to the third step - the proposal of a knowledge map presenting the proposal of a model for the eco-innovation integration into the innovation process of companies in Slovakia to increase their performance.

Based on the above findings, a force field for the implementation of the innovation process of innovation and eco-innovation in Slovakia was developed (Table 1). It represents the pros and cons of innovation forces. It means pro-innovation forces that support the innovation process of implementing innovations and vice versa. These innovative forces prevent the implementation of the innovation process in companies in Slovakia, as Slovak companies perceive it based on a survey conducted by us. The force field points to innovative forces that support innovation and the innovation process and the interest in its development in Slovakia, such as interest in implementing innovations, using an open innovation system to implement innovations, and companies trying to implement innovations eco-innovation to a greater extent.

On the contrary, companies in Slovakia feel the anti-innovative forces as the facts that prevent them from developing innovations and the innovation process in Slovakia. They include lack of financial resources, high bureaucracy, lack of relevant information for creating innovations, low awareness of eco-innovation, cooperation in implementing the innovation process, increased costs for implementing innovations, lack of qualified workforce, high level of risk and now a pandemic situation. It operates more or less only at the sectoral level (suppliers and customers).

Table 1 The force field of the implementation of the innovation process of ecological innovations in Slovakia

Pro-innovation forces	Anti-innovation forces
Interest in implementing innovations	Lack of financial resources
Using an open innovation system to implement innovations	High bureaucracy
Companies try to implement eco-innovation to a greater extent	Lack of relevant information for creating innovations
	Low awareness of eco-innovation
	Cooperation in the implementation of the innovation process
	High costs for the implementation of innovations
	Lack of qualified workforce
	High level of risk
	Pandemic

After collecting the data, it is possible to proceed to the third step, namely the proposal of a knowledge map presenting the proposal of a model for the eco-innovation integration into the innovation process of companies in Slovakia to increase their performance (Figure 1). The model itself is based on the analysis process related to the implementation of the innovation process. As we found out through the analysis, it is based on the principle of 3C - Consumers - Eco-innovation adopters, Competitions - stakeholders and Change - an innovation process leading to innovations as well as eco-innovations.

It represents the system management of external and internal material flows and related information flows, representing the modelling of these processes to increase the performance of business entities through the implementation of innovations with a focus on eco-innovation. The proposal of a knowledge map representing a model of integrating eco-innovation into companies' innovation process in Slovakia to increase their performance by designing a system of planning, synchronization, management, implementation, and control of internal and external flows, which is the basic role of logistics. The proposed model of the knowledge map presents a model for the eco-innovation integration into the innovation process of companies in Slovakia to increase their performance, presenting the proposal of the system of planning, synchronization, management, implementation**,** and control of internal and external flows. The direction of the arrows in Figure 1 shows the direction of flows within the internal as well as external environment of companies. This is the basic task of logistics. The proposed model of the knowledge map as a logistic model aims to achieve the highest flexibility, accuracy, economy, and innovations support within the innovation system in Slovakia to integrate eco-innovation into the innovation process of companies.

In addition to the collected data, the proposal of the model is also based on motivational factors for the eco-innovations introduction, which are necessary for the implementation and introduction of innovations into the innovation process of business subjects and practice. Díaz-García et al. [21], who summarized the motivational factors for the introduction of eco-innovations, characterized their determinants in general. We divide them into three categories:

1. Macro–level. It includes the already mentioned regulations that are part of the so-called Porter's hypothesis that states that regulations concerning the environment stimulate innovation and lead to a "win-win" situation at the end of which the negative impact on the environment decreases and the competitiveness of companies increases. Businesses respond to environmental policy interventions, through which governments must use the internal power of private companies, which are also motivated by customer interest and voluntary codes of conduct.

2. Meso-level. The motivating factors that fall into this category are characterized especially by changing market conditions caused mainly by changes in consumer behaviour of customers (increasing awareness of the need to protect the environment, modern trends, etc.). The theory represents the mezzo-level mainly by dominant subjects and their behaviour in the range of micro and macro-level [22]. In this case, the meso-level is characterized by organizations, institutions, groups, and public policy [23].

3. Micro-level. It includes mainly internal incentives and the state of small and medium enterprises. The authors refer to the structural characteristics of companies (e.g., size, age), their strategy and business logic (e.g., cost savings, expansion in the market) or their technological competencies (e.g., research and development), the qualifications of staff and management, cooperation, and networking with other sectoral partners). [21], figure 1, on the right - Motivational factors for the implementation of eco-innovation. Subsequently, based on the data collected from the previous steps, the model is designed to reflect the needs of businesses, their opportunities for the development of eco-innovation and to eliminate anti-innovative forces within the force field. To eliminate them within the force field and the motivating factors that include the tools to support innovation from the individual levels, it was also elaborated other subjects, such as government, scientific and technological organizations, research and development, universities, investors, and investors organization support.

Within the internal flows of the proposed model in companies, the innovation process should be based on inventions developed into innovation opportunities in Research&Development (R&D) as well as technological research, which would result in the testing of R&D outputs representing product or process innovations. Subsequently, these outputs of the innovation process need to be tested on the market. For the correct proposal of a marketing plan to place the innovation on the market because due to increasing innovation pressure from competitors, tendentious saturation of many markets and hastened technological development, product success is becoming increasingly difficult to achieve. Figure 1 - middle part of the model - innovation process, which is based on nonlinear models of the innovation process representing an open approach to the innovation process, which facilitates the penetration of information to support innovation in organizations but also countries, which currently support innovative ICT platforms stimulating innovation [20]. The result of the innovation process is consequently Figure 1 - middle part of the model - innovation process, which is based on nonlinear models of the innovation process representing an open approach to the innovation process, which facilitates the penetration of information to support innovation in organizations but also countries, which currently support innovative ICT platforms stimulating innovation [20]. The result of the innovation process is consequently innovation and ecological innovation.

PROPOSAL OF A MODEL FOR THE ECO-INNOVATION INTEGRATION INTO THE INNOVATION PROCESS OF COMPANIES IN SLOVAKIA TO INCREASE THEIR PERFORMANCE

Erika Loučanová; Miriam Olšiaková

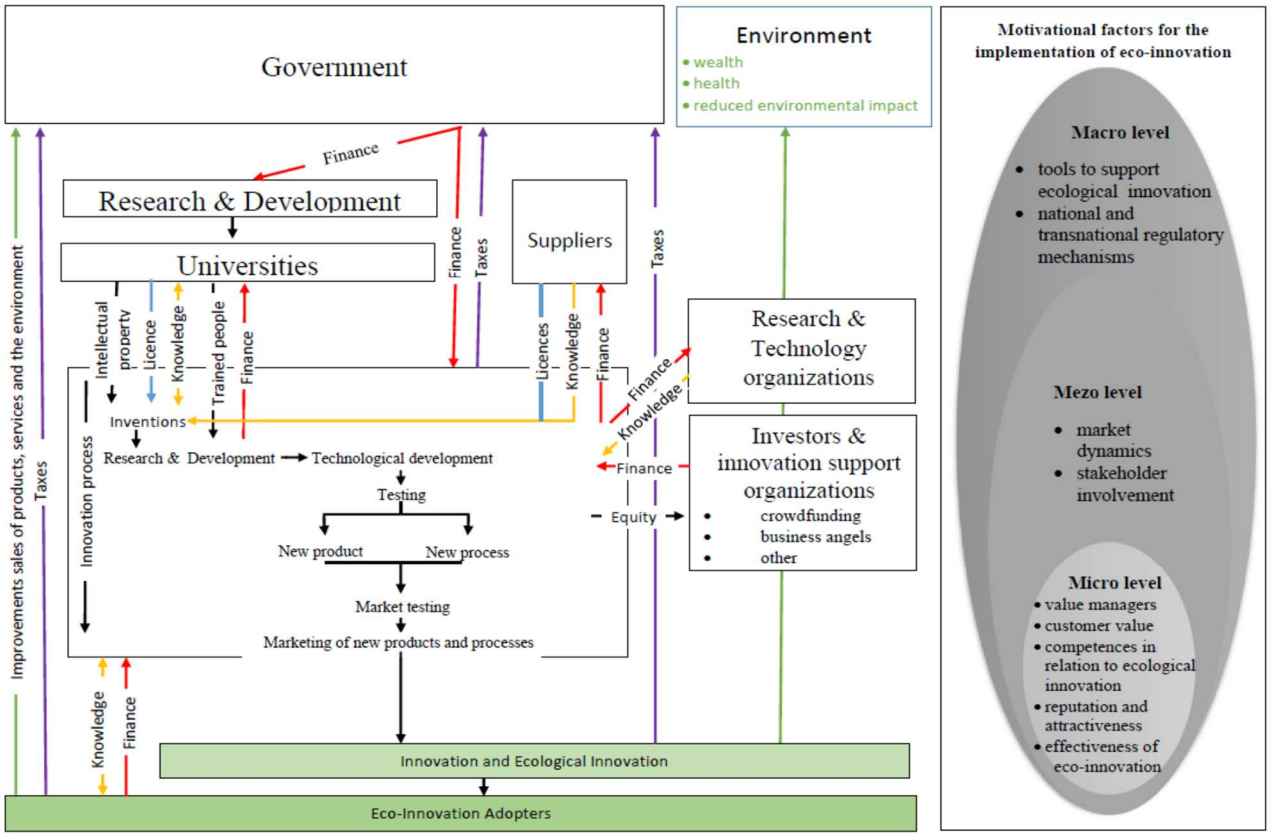

Figure 1 The proposal of a model for the eco-innovation integration into the innovation process of companies in Slovakia in to increase their performance

As it is reported by Trommsdorff and Steihoff [24], although the individual success factors or better methodologies supporting the marketing of innovation are known, the failure to succeed with a product is from 4 to 90%, depending on the business area and measurement methodology. Therefore, from a time point of view, it is very important to correctly estimate the success of innovation in terms of both qualitative and quantitative point of view. It means to evaluate the effectiveness of the implemented project for innovation. A bad estimate can cause the project team large losses and damage to goodwill. Therefore, it is appropriate to implement a two-way flow of knowledge to meet the needs of eco-innovation adopters, which are then transformed for the company into a flow of finance - income from sales of innovation, taxes for the government from these sales and the overall impact of improvements sales of products, services and the environment.

Successful innovations and eco-innovations then present "any quantitative or qualitative purposeful change representing a positive effect" [19] for companies as well as eco-innovation adopters, or innovation adopters for which they are intended, Figure 1– low part of figuring – eco-innovation adopters.

One interesting idea regarding "innovativeness" explains the degree to which an individual or another unit of adoption accepts earlier new ideas compared to other members of a system. Following this idea, Rogers and Mitsufuji [25] divided consumers into six adopter categories: Innovators, Early Adopters, Early Majorities, Late Majorities, and Laggards. Consumers in each category share general unique characteristics specific to their category. Early Adopters accept innovation and also become opinion leaders. Moore [26] supposes that Innovators and Early Adaptors are consumers who buy innovative products even if no one around them owns such a product. Early Majorities are rather market pragmatists and conservatives. They do not try an innovation until others do so. Understanding both Early Adopters and Early Majorities is important to find the best ways to encourage wide use of innovations on the market.

Rogers and Mitsufiji [25] states that socioeconomic status is related to innovativeness. Early Adopters have more years of education and higher social status than Late Majorities. Status is deduced from variables such as income, lifestyle, and wealth. Regarding the idea, Early Adopters and Early Majorities share an appreciation for new technology, while Late Majorities tend to dislike using sophisticated technology. Early Adopters are more likely to try new technology if it addresses issues they are interested in, while Early Majorities are more pragmatic and traditional than Early Adopters [27].

Inventions for innovation processes in companies should be based on licenses, knowledge or incentives also from the external environment, directed from research and development, universities, suppliers, research technology organizations, investors and innovation support organizations such as crowdfunding, not forgetting also on adopters. This flow of inventions, knowledge, licenses, and incentives for the innovation process also represents a flow of funds, which either supports the research and development of innovation or subjects providing these incentives or supports implementing the innovation process from investors and other stakeholders. The exchange of information, inventions, but also material flows also represents funds directed to the state budget in the form of various types of taxes, which the government should use through the tools of the innovation system to support the development of innovation and thus the eco-innovation process in companies, figure 1 – upper part of the Figure – Government, Research and Development, Universities, Suppliers, Research and Technology organizations, Investors & innovation support organizations and Environment.

This presents a method how to obtain money and finance to capitalize on various projects. Considering possibilities provided by the innovation system of the model supporting innovation, subjects who seek funds for project financing reach a potentially varied audience, which can support their innovation projects. Experts, lawyers, and policymakers usually describe these alternatives for financing as "disruptive", and "democratizing" characteristics. These features also result from the concept of monetary and financial ecologies, which assumes that the processes of capitalizing are variegated, intermediated and uneven. Thus, it is a new, rendered economic space that could challenge established funding practices. To reach critical progress in the economy, it is necessary to develop the idea of "ecologies", which is elaborated in the literature dealing with money and finances. The financial and monetary ecological issues were initially developed to consider the endurance of "relic" forms of financial issues during the 1990s. In this case, the ecology idea applies an approach to money and finance geographies without considering monetary and financial systems operations to be singular and defined by space and time logic of a global capital circuit. Money and finance geographies include discrete and dynamic constitutive ecologies. In turn, the ecologies above consist of specific configurations. They are more or less reproducible over time. These relational processes, which entail distinctive combinations of financial knowledge, institutional and intermediary techniques and expert and popular subjectivities, unfold across the model. Therefore, distinctive ecologies emerge in various places [28-30]. The direction of the arrows in Figure 1 shows the direction of flows among individual parts of the model.

The whole proposal of the model for eco-innovation integration into companies' innovation process in Slovakia to increase their performance subsequently aims to support the environment and increase the efficiency of companies in Slovakia. Model is proposed to strengthen pro-innovation forces and eliminate anti-innovation forces of the force field identified for Slovak companies. It means eliminating lack of financial resources, lack of relevant information for creating innovations, low awareness of eco-innovation, cooperation in the implementation of the innovation process, high costs for the implementation of innovations.

The European Union has long been searching ways to promote innovation, from supporting research and industrial policies in the 1970s, through action plans in the 1990s and the Lisbon Strategy from 2000, to the Europe 2020 strategy from 2010, which is currently being updated by ten priorities of Jean-Claude Juncker who is the President of the European Commission. Regarding a recent study, innovation policy has evolved to be understood as an overall term that includes research, industry, and education policies and policies keys to the innovation process, such as funding, taxation, regulation, standards, and intellectual property rights. Efforts to promote innovation are also part of many EU programs, such as the Digital Single Market [31].

Innovation policies aim to improve and facilitate interactions among the innovation system actors to enhance the whole system's performance. Based on the proposed model mentioned above, it is obvious that more factors influence innovation and ecological innovation. When addressing innovation, policymakers should consider a wide range of aspects.

4 Conclusions

This paper describes the proposal of a model for the eco-innovation integration into the innovation process of companies in Slovakia with the aim to increase their performance. The creation of a model in which ecological innovation can contribute to increased performance of companies in Slovakia and sustainable development requires a logistic model of the system of planning, synchronization, management, implementation and control of internal and external flows for the highest flexibility, accuracy, economy and innovation support within the innovation system in Slovakia in the integration of ecological innovations into the innovation process of companies. The model is based on determinants influencing the development of eco-innovation. Attention was paid not only to determinants that positively impact the creation and implementation of eco-innovation, but we mainly focused on determinants that negatively impact their creation. The application of the proposed model was constructed to increase the efficiency of the innovation process of companies for the implementation of ecological innovations in Slovakia. If companies want to succeed in a market that is often characterized by strong competition, they should focus on creating innovations implemented on the principle of sustainable development. It means they

should think ecologically during the production, distribution or sales, and of course, to offer customers products that meet environmental standards. This effort also affects the activities of the European Union, which is also interested in the issue of environmental protection and the sustainability of economic development, resulting in specific programs that are directly related to the green economy and the sustainable environment. Despite the above mentioned, when applying the model, it is necessary to consider certain limitations that their using is difficult in the conditions of the Slovak Republic. At present, these are mainly restrictions associated with the Covid-19 pandemic, which significantly affects the Slovak economy, so the possibilities of the state support for innovation are changing very dynamically. Therefore, the model should respond correctly and flexibly to the macroeconomic and microeconomic environment, legislative factors, and other country factors. The state sets the conditions that the company must respect in its business activities and related innovative activities. These factors represent the design limits of this model.

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SIGNIFICANCE OF LOGISTIC CONTROLLING AS A BASE FOR FILLING GOALS OF BUSINESS STRATEGY
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SIGNIFICANCE OF LOGISTIC CONTROLLING AS A BASE FOR FILLING GOALS OF BUSINESS STRATEGY

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Keywords: logistic, controlling, variance, comparation analyses, optimize
Abstract: Logistics costs form one group of total business costs that fundamentally affect the performance of the firm, which is part of the business strategy orientated to minimize costs. Logistics controlling has to be part of the business management system for a reasonable evaluation of the performance of logistic processes and their influence to profit. The main goal of this paper to points to the significance of synergy of economic analysis, statistics, logistic controlling, dashboarding for filling the aims of business strategy. Effective logistic management the means of optimizing logistics costs, improvement of logistic processes, and achieving a business profit. We use economic, statistical analyses, controlling, dashboarding, and a questionary survey in this paper. An effective tool for improving the goals of business strategy in the logistic area is the implementation of logistics controlling presented by software EIS Dominant, results of analyses by a dashboarding, logistic performance by statistic, and economic analyses. Results of all analyses point to reducing logistic costs and improving the financial situation. This fact is an effective instrument for logistic improvement and innovation in logistic processes, implementation of logistics controlling. Logistics controlling is a system of rules which helps achieve business goals by minimizing costs.

1 Introduction

Today, firms operate in a complex competitive environment that requires fundamental changes in approaches, conceptions, methods, and instruments as is logistic controlling [1]. Business strategy is orientated on minimalization costs in the firms and logistic costs create one type of total business costs [2]. The main goal of this paper to points to the significance of synergy of economic analysis, statistics, logistic controlling, dashboarding for filling the aims of business strategy. Through economic and statistical analyses we show the significance of logistic controlling and its implementation in the firms. Management approaches these costs through the Balance ScoreCard approach, which allows to track logistics costs in terms of their financial perspective (Figure 1) [3]. BSC approach is orientated to logistic processes too. It is a tool for the efficient management of logistics processes.

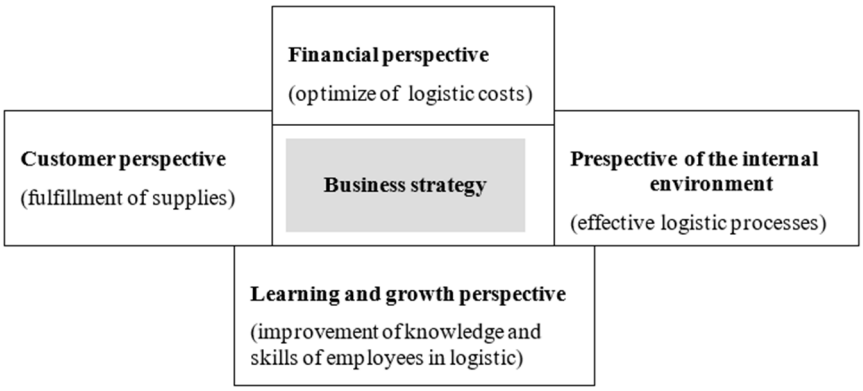

Figure 1 BSC approach for implementation logistics controlling
Source: own source

The basis of the BSC approach as a strategic instrument is to monitor logistic costs and their influence on the financial structure, sources and performance indicators [4,5]. Management of logistics costs requires a change of approach in terms of ensuring direct information flows on the occurrence of generic costs of logistics processes [6]. The base of business strategy is building of an information system based on accounting and reporting, connecting this

system with the company's management system so that information on logistic costs of logistics processes [7,8]. The reason for these changes is to optimize logistics costs and their reduction[9]. An effective tool for the implementation of these measures is the introduction of logistics controlling. Logistics is an important area in the IPO (input, process, output) chain in the firm. The chain of logistics activities ensures the smooth running of the production process and each logistics activity is associated with the occurrence of logistics costs [10]. These costs represent non-negligible items that greatly affect the firm's overall profit as well as profit generation. Monitoring of logistic costs in the concept of logistics processes is a base for identifying rationalization measures, innovations, improvements. Logistic controlling (Figure 2) creates part of the management information system in the firms. Logistics controlling means to fill business goals, to fill up business rules, to achieve profit, to keep law, norms, to guide business activities [11]. The management information system needs new innovations in the field of logistics from the perspective of Logistics 4.0 and therefore it is necessary to change the approach in companies and implement tools such as logistics controlling [12].

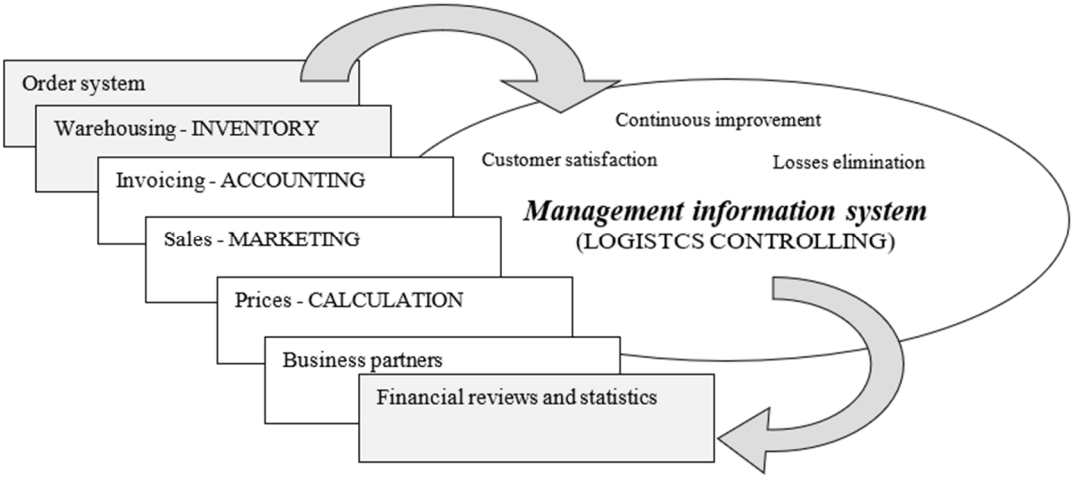

Figure 2 Business management information system with logistics controlling
Source: own source

Logistics costs (Figure 3) are cost that creating by logistic processes in the frame of the IPO chain in business. They are reported as logistics chain costs or costs for ordering, supply, material handling, storage, packaging, transport, and distribution. They are expressed in absolute terms or assigned to a unit of logistics performance, for the product, to order, etc. Logistics costs largely affect the number of total costs, as they are reflected mainly in the category of overhead costs, the share of which shows a growing trend in companies. Multiple- method analysis brings advantages for minimizing logistic costs and their checking, planning, leading [13,14].

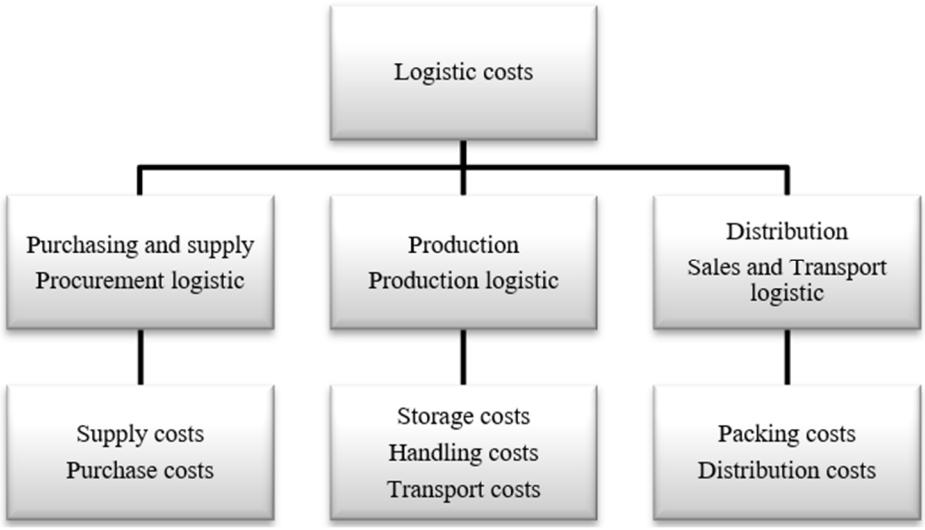

Figure 3 Type of logistic costs
Source: own source

Logistics costs become unproductive e.g. in the event of an unplanned method of procuring stocks, in the event of an excessive storage of stocks, in the event of an inappropriate choice of mode of transport, in the case of uncontrolled handling of goods what we can receive by accounting system in logistic [15]. These reasons also force managers, to look for solving, how to streamline the system of monitoring and control of costs within individual logistics processes. The theory of constraints is a supporting element of logistic controlling and that is important to integrate it in logistic controlling [16]. Logistic cost groups form an integral part of total costs and create customer value chain analysis [17]. Reducing total costs in companies is one of the business goals of the business strategy that must be orientated to human resources in logistic processes too and their motivation is a point to optimize costs in the firm [18]. Reducing total costs influences the profit and efficiency of the business. Logistic controlling is one instrument of how to check logistic costs. It is a concept that coordinates planning, organization, control, information flows, leading of people in logistic processes, analyze logistic risks, aims of green logistics, the benefits of reverse logistics [19,20]. Controlling mainly includes the following activities: finding out the current state (analysis), forecasting, setting goals, planning, and budgeting, checking for deviations from the plan, determining the causes of deviations, setting new goals in business strategy. The main controlling concept is based on comparative analyses for plan and actual logistic costs. Identifying deviations and causes of these deviations, monitoring the impact of deviations on the fulfillment of a predetermined goal, which is measurable by economic indicators. Controlling is based on defining the goals that the company wants to achieve in the logistic area. An important goal of business strategy is to reduce logistics costs.

2 Methodology

As part of the research, we followed a 5-step algorithm (Figure 4), which represented the following phases of solving the research problem: a collection of data from internal sources of the selected firm, implementation of a questionnaire survey on the use of management tools in companies, implementation of software support instrument EIS for doing logistic controlling, the realization of economic analyzed, evaluation of results of economic analyses and suggest innovative solutions. Through this algorithm, we tried to point out the importance and possibilities of using logistics controlling the firms as a tool for meeting the goals of corporate strategy that is orientated to minimize logistic costs.

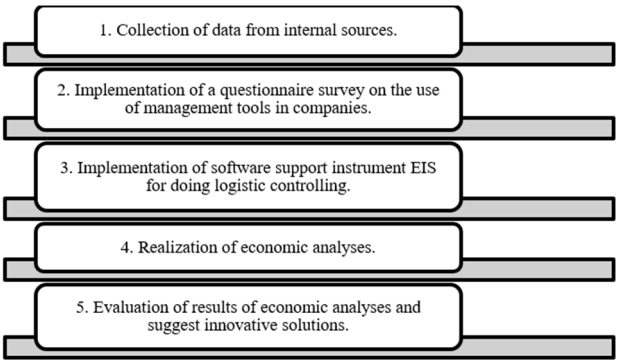

Figure 4 Algorithm of methodology
Source: own source

Collection of data from internal sources

In this phase, we collected data from management information system in the firm and from financial and accounting systems as Gradient and Omega that are used in this firm. Those information systems offered us all the required information for doing economic analyses. All information we prepared in the right form, in the same time period for the year 2019 and all 12 months.

Implementation of a questionnaire survey on the use of management tools in companies

A questionnaire survey on the use of management tools was realized by the VEGA project in the year 2019. The survey was prepared for industrial companies in Slovakia, in various areas of the industry, for 540 companies and the questionnaire had 10 questions. The companies were addressed by email, phone, personal meetings.

Implementation of software support instrument EIS for doing logistic controlling

For project realization, we obtained software support from firm Dominant Prešov named EIS Dominant. This software application is used in firms and it is very easy for education too. In the education process, we used this application. This application was used for solving project of logistic costs.

Realization of economic analyses

We used for economic analyses statistical, financial, economic indicators (formula 1-7).

Structure of stocks

They express the share of a part of the statistical file in the total file. Absolute values are converted to a relative percentage (%) that has a higher significance. We can use this indicator to determine the structure of production, inventories, costs, assets of the company. Xi – various indicator – stocks, costs, assets, production, revenues.

$$\frac{Xi}{\check{S}=\sum x_i} \quad (1)$$

Basic index

We compare by the ratio of the current period with a predetermined base period, the base period is constant throughout the time series. The basic period is denoted by the symbol (0), the current period is denoted by the symbol (1), (q) - costs.

$$\frac{q_1}{q_0}, \frac{q_2}{q_0}, \frac{q_3}{q_0}, \ldots, \frac{q_n}{q_0} \quad (2)$$

Chain index

We compare the ratio of two consecutive periods, the basis of comparison is not determined as a constant. The comparison is performed in chronological order in the monitored time series.

$$\frac{q_1}{q_0}, \frac{q_2}{q_1}, \frac{q_3}{q_2}, \ldots, \frac{q_n}{q_{n-1}} \quad (3)$$

Growth coefficient

It expresses how many times the value (Yt) in the period (t) has increased compared to the value (Yt-1) in period (t-1).

$$k_t = \frac{y_t}{y_{t-1}}, t = 2, \ldots, n \quad (4)$$

Increment coefficient

It expresses how many times the increment of the variable (Y) was greater or less than in the previous period.

$$k\Delta_t = \frac{\Delta y_t}{y_{t-1}} = \frac{y_t - y_{t-1}}{y_{t-1}} \quad (5)$$

Growth rate

It is the growth coefficient expressed as a percentage (%). It expresses the percentage by which the value (Yt) of the time series at the time (t) increased or decreased compared to the value (Yt-1) from the previous period.

$$T_t = \frac{y_t}{y_{t-1}} * 100\% \quad (6)$$

Increment rate

It is a relative increase expressed as a percentage (%) and expresses how much it increased, the value of the time series in time (t) decreased compared to the value from the previous period.

$$T\Delta_t = \frac{\Delta y_t}{y_{t-1}} = \frac{y_t - y_{t-1}}{y_{t-1}} * 100\% \quad (7)$$

Evaluation of results of economic analyses and suggest innovative solutions

Logistic costs were evaluated by selected indicators after economic analyses by using the EIS system for logistic controlling. In this phase, we obtained a view to fill the goals of business strategy orientated to minimize logistic costs.

3 Result and discussion

In the research of logistic costs, we followed a 5-step algorithm. Through this algorithm, we point out the importance and possibilities of using logistics controlling the firms as a tool for meeting the goals of corporate strategy that is orientated to minimize logistic costs. Economic indicators are important information for the creation of profit.

Collection of data from internal sources

In this phase, we collected data (Table 1) from management information system in the firm and from financial and accounting systems as Gradient and Omega. Those information systems offered us all the required information for doing economic analyses. We analyzed the year 2019 for 12 months. We obtained information on the type of stocks – material stocks, work in progress, finished products, the total cost in the firm, production, inventory turnover. That information is important for economic indicators.

Table 1 Information for economic analyses during 12 monts in year 2019

Month /Type of stocks	January	February	March	April	May	June	July	August	September	October	November	December
Finished products (€)	1 992 538	3 821 691	3 075 872	2 835 861	2 071 974	3 034 068	3 880 435	3 162 962	3 501 903	3 288 277	5 038 853	3 864 802
Work in progress (€)	1 012 232	1 299 237	1 692 581	1 760 328	1 860 075	1 807 219	1 552 845	1 628 198	2 307 643	1 710 181	1 295 030	1 150 214
Material stocks (€)	3 633 410	4 577 672	4 133 047	4 033 729	5 121 530	3 906 272	3 630 568	3 811 641	4 554 790	4 461 385	3 446 510	3 462 566
Total costs (€)	6 638 179	9 698 600	8 901 500	8 629 917	9 053 580	8 747 560	9 063 848	8 602 801	10 364 336	9 459 844	9 780 394	8 477 582
Production (€)	10 679 190	10 859 610	10 400 190	10 439 250	13 130 670	15 177 600	14 002 080	9 968 670	15 946 710	23 146 770	17 725 800	14 720 040
Inventory turnover (€)	10 985 280	9 970 560	12 016 320	11 050 560	12 925 440	14 504 640	15 478 080	9 165 120	16 778 880	21 651 840	19 983 360	17 613 120

Source: internal sources of the firm

SIGNIFICANCE OF LOGISTIC CONTROLLING AS A BASE FOR FILLING GOALS OF BUSINESS STRATEGY
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Implementation of a questionnaire survey on the use of management tools in companies

A questionnaire survey on the use of management tools (figure 5) was realized by the VEGA project in the year 2019. The results of a questionnaire survey show to using various approaches in business processes in the firms for filling goals of the business strategy. With these tools, companies can influence and optimize their business processes. We focused on the use of controlling in companies, which represents 24%. This result is not satisfactory due to the barriers that arise in the implementation of controlling in companies and at the same time the financial resources that are needed to start controlling. Significant findings were the application of the quality management system, which represents 65% representation in companies. This system also enables the control of logistics processes that have an impact on the fulfillment of business strategy goals. From the point of view of the logistical view of management tools, we can state that companies use process management 35%, JIT 29%, Kaizen 18%, ABC 16%. These tools offer opportunities to optimize logistics costs, which is beneficial for meeting the goals of the business strategy.

Figure 5 Using managerial instrumens in the firms in Slovakia
Source: own research

Implementation of software support instrument EIS for doing logistic controlling

For project realization, we obtained software Dominant (Figure 6) Prešov named EIS Dominant. This software contains database as Financial controlling, Value based management, Balanced Score Card, Cost controlling. The results of those parts are presented by dashboarding. Dashboarding is support instrument for decision and for filling the business goals.

Figure 6 Illustration : Dashboarding of EIS system
Source: EIS system

This Dominant software contains modules of various controlling. The modules are focused on financial, economic, marketing, knowledge areas. The important contains financial controlling - statements balance sheet, income statement, cash flow, financial analysis, economic analysis, bankruptcy models, working capital, financial plan, and TOP reporting. The second model is cost controlling, which includes budgets, calculations, cost analysis, consumption at the centers. The third module is the marketing controlling focuses on the company's strategy, BSC performance approach, company value, creditworthiness, value-based management. The fourth module is knowledge controlling, which contains a financial map, EVA analysis, financial indicators, and their impact on meeting the objectives of corporate strategy. It is reporting module where all important information of three modules financial, cost, marketing controlling.

Realization of economic analyses

We used for economic analyses statistical, financial, economic indicators (formulas 1-7). The first analysis was focused on the structure of inventories (Table 2) in the company during the year 2019. We found that material stocks account for 35-56%, work in progress 13-22%, finished products 22-52%. Based on research for a "healthy business", material costs should be 30%, work in progress 40%, and finished products 30%. This company has a high stock of material in stock because in some months it exceeds 56% which should be 30%. This state of stocks creates problems for them in increasing the costs of storage, maintenance of stocks, insurance of stocks, there is a devaluation of stocks, stocks tie up funds that the company could use to minimize them. Work in progress stocks can be around 40%. In the company, these stocks are represented in the range of 13-22%. The company does not store unfinished products, but tries to end the production process and thus minimizes the costs associated with unfinished production. Finished production in the company is in the range of 22-52%, which is optimal for

the conditions of "healthy companies". The level of 52% could be reduced, which would enable the company to satisfy demand, financial resources for new production processes, expansion of product range. Overall, we can say that the inventory structure in the company is optimal, even though there are possible alternatives to the innovation of the inventory structure.

Table 2 Analyses of structure of stocks

Structure of stocks	2019	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Okt	Nov	Dec
material stocks	45.40%	54.74%	47.20%	46.43%	46.74%	56.57%	44.66%	40.06%	44.31%	43.95%	47.16%	35.24%	40.84%
work in progress stocks	17.76%	15.25%	13.40%	19.01%	20.40%	20.55%	20.66%	17.13%	18.93%	22.27%	18.08%	13.24%	13.57%
finished production	36.84%	30.02%	39.40%	34.55%	32.86%	22.89%	34.68%	42.81%	36.77%	33.79%	34.76%	51.52%	45.59%

Source: own processing

The second analysis (Table 3) focused on the base and chain index, which indicates the development of inventory in individual months. In January, it was not possible to determine the index due to the missing value of Inventory in the previous month and year. The basis for solving the basic index was the month of January in 2019 and the state of inventories in individual months was compared with January. The values of the basic index are above the coefficient (1), which means an increase in total stocks (material stocks, work in progress, finished products) in each month. This development represents a benefit for supply logistics because the optimal inventory turnover takes place, which reduces the company's costs and raises funds for a new production process. When addressing the chain index, both growth and decline in inventories were recorded when comparing previous months. In March, April, June, and August, October, December there was an overall decrease in inventories compared to the previous month. Inventories have risen in recent months. Overall, we can say that stocks were replenished according to market requirements, production process, customers.

Table 3 Index analyses

2019	Feb	Mar	Apr	May	June	July	Aug	Sept	Okt	Nov	Dec
Basic index	1.46	1.34	1.30	1.36	1.32	1.37	1.30	1.56	1.43	1.47	1.28
Chain index	1.46	0.92	0.97	1.05	0.97	1.04	0.95	1.20	0.91	1.03	0.87

Source: own processing

The analysis of time series (Table 4) points to the trend of development of stocks and their types in the company. Inventories recorded an increase and a decrease in individual months. This movement of stocks adapts to the production process and market requirements. The highest increase in inventories was recorded in February by 46%, the lowest increase was in November at 3%. Regarding the decrease in inventories, the lowest decrease was recorded in April and June by 3%, the highest decrease in inventories was in December at 13%.

Table 4 Time series analyses

2019	Feb	Mar	Apr	May	June	July	Aug	Sept	Okt	Nov	Dec
Growth coefficient	1.46	0.92	0.97	1.05	0.97	1.04	0.95	1.20	0.91	1.03	0.87
Increment coefficient	0.46	-0.08	-0.03	0.05	-0.03	0.04	-0.05	0.20	-0.09	0.03	-0.13
Growth rate	146%	92%	97%	105%	97%	104%	95%	120%	91%	103%	87%
Increment rate	46%	-8%	-3%	5%	-3%	4%	-5%	20%	-9%	3%	-13%

Source: own processing

Evaluation of results of economic analyses and suggest innovative solutions

Logistic costs were evaluated by selected indicators after economic analyses by using the EIS system for logistic controlling. In this phase, we obtained a view to fill the goals of business strategy orientated to minimize logistic costs. Reducing logistics costs in the company requires a change in approach in the management of

individual logistics activities or. processes, valuation of these processes by determining the relevant amount of logistics costs, and moving towards process optimization through the use of new approaches to streamline activities that will ultimately bring the company an economic effect. The solution to the issue of reducing costs is primarily the introduction of new approaches and methods in logistics, which are not focused only on the financial side, but on the organizational, technical, technological, environmental, etc. The structure of logistics costs (Figure 7) represents 45% of the material, 37% of final products, 18% of work in progress. In terms of efficiency, the amount of material costs is above the level of 20%, which represents the commitment of funds, depreciation of inventories, storage costs, insurance costs, operation of storage facilities, etc. In practice, the operational inventory management approach through the JIT approach is preferred in practice today. The development of stocks, monitored in the form of an index - basic and chain, points to fluctuating developments. This fact indicates a change in stocks in individual months, which may be linked to the need for the production process.

Logistics costs also affect the level of profit in the company. They are part of the total business costs. When calculating corporate profit, we use the difference between sales and costs (Table 5). Despite the fact that logistics costs make up 18-40% of the total costs, the company generates a profit, and logistics costs do not significantly affect the company's profit. However, monitoring the development of logistics costs is very important due to the implementation of innovations in logistics processes, which can affect the amount of logistics costs and thus increase the company's profit

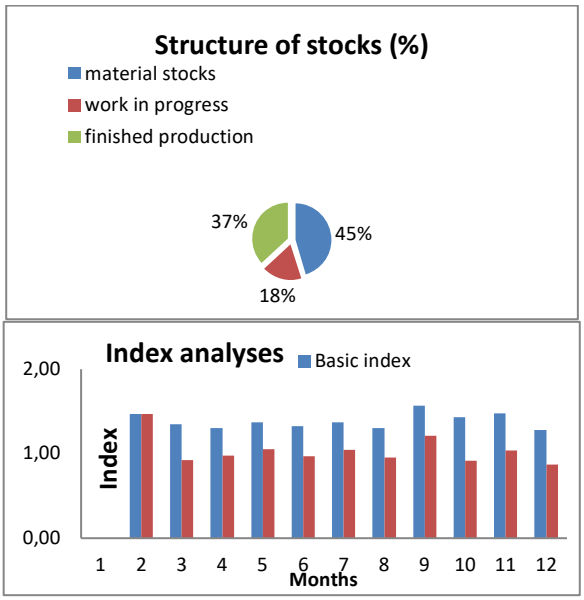

Figure 7 Dashboarding - Structure of stocks, Index analyses
Source: EIS system

Table 5 Profit formation

Month /Type of stocks	January	February	March	April	May	June	July	August	September	October	November	December
Total costs (€)	6 638 179	9 698 600	8 901 500	8 629 917	9 053 580	8 747 560	9 063 848	8 602 801	10 364 336	9 459 844	9 780 394	8 477 582
Inventory turnover (€)	10 985 280	9 970 560	12 016 320	11 050 560	12 925 440	14 504 640	15 478 080	9 165 120	16 778 880	21 651 840	19 983 360	17 613 120
Profit (€)	4 347 101	271 960	3 114 820	2 420 643	3 871 860	5 757 080	6 414 232	562 319	6 414 544	12 191 996	10 202 966	9 135 538

Source: internal sources of the firm

4 Conclusions

The chain of logistics processes is tied to logistics costs as an economic category, which is important to manage, monitor, evaluate and influence in terms of achieving economic efficiency of logistic processes. The best recommendation is to use managerial tools and approaches that will not only reduce logistics costs but will also contribute to changes in the organization of work in the company, innovation, environmental and social responsibility. In this paper, we showed one of the approaches how to check logistic costs and to view the trend of logistic inventories by logistic controlling. This approach has benefits for the company. It checks logistic costs, shows reserves in logistic processes, views waste, and others. The structure of stocks in the company is optimal, there is an effective turnover of stocks, which ensures a continuous production process. Within continuous improvement of logistic processes in the firm is important to use a system aimed at the systematic detection and elimination of failures in the production process. Continuous improvement in the logistic processes is realized through innovative steps in the form of changes of buying, supply chain, store building, the layout of store place, employees of the store. The use of logistics controlling in the decision process is possible to use in various companies while accepting the conditions of its implementation and using. The overall impact of using logistic controlling is reflected in the minimization of the production - logistic costs.

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simulation for streamlining production in the mining and building industry".

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APPLICATION OF PHYSICAL INTERNET IN INTRALOGISTICS – A SIMULATION STUDY

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Keywords: logistics, Physical Internet, intralogistics, simulation
Abstract: One of the biggest challenges today is to make traditional systems more sustainable. Physical Internet (PI, π) based logistics systems provide one of the most defining solutions. In our opinion, it is worthwhile to deal with the intralogistics conversion of the Physical Internet because traditional systems can no longer operate with sufficient efficiency to meet growing customer expectations and demands. This research focuses on restructuring a factory from its traditional operating to a PI-based system using our previously defined intralogistics components. The article surveys the possibility of creating PI-hub and virtual PI-hub in a factory process. The warehouses were converted to PI-hubs, and virtual PI-hubs were placed near the two manufacturing to create a more flexible structure. We created a simulation study in AnyLogic where we examine the efficiency achievable by automated guided vehicles (AGVs) in a PI-based system. The results were compared based on the traditional and PI-based systems. Based on the simulation the inefficiency of the PI-based system is lower (by ~18%) at higher control event values. This allows achieving a more efficient, flexible, sustainable, and balanced operation.

1 Introduction

Achieving sustainable operations is currently one of the biggest challenges in both research and industry. In logistics, traditional transport, storing, and material handling methodologies cannot effectively increase individualization, demand, and quality. Physical Internet (PI, π) provides a new system, a vision presented as the future logistics system, breaking with all traditional methodologies, and building the new system on the model of the flow of information based on the Digital Internet data packet. PI specifies a holistic design based on the connectivity of the physical, digital, and operational worlds.

The Physical Internet's basic idea has already appeared in the literature in several different areas [1,2]. In recent years, there has been an increasing focus on exploring PI-based systems, with numerous studies on extralogistics systems [3], but only a few publications on intralogistics systems. Intralogistics processes provide the core system for companies and the focus of operational logistics activities. This is also a significant cost factor, so we consider it essential to examine the Physical Internet's feasibility in intralogistics systems as a forward-looking concept. The implementation of the Physical Internet requires a paradigm shift. The processes and tools must be examined from a new perspective. Like Industry 4.0, the focus is not only on the tools used but also on the way we are thinking. We determined the intralogistics transformation of each PI component. Without exception, all components have an internal system version. In the case of π-container, which plays a crucial role in extralogistics systems, we proposed using the Euro container, the so called KLT containers, which are already frequently used in industry. The abbreviation KLT comes from the German word *Kleinladungsträger*. The extralogistics and intralogistics versions of the π-container are shown in Figure 1. This gives the standard unit by which the operation can be based on PI.

Examining the Industry 4.0 tool applicability in PI systems, the simulation seems one of the most prominent [4]. As a reason for this, we also support the theoretical model with simulation in this research, with which we can obtain data-supported results at a much shorter time and a lower cost compared to experiments on real systems.

This research focuses on the intralogistics conversion of the Physical Internet. Using the intralogistics components identified in our previous research, we deal with restructuring a simpler factory into a Physical Internet-based system. We examine the five types of products' routes at the factory, which are moved between

each station by automated guided vehicles (AGVs). We created the Physical Internet-based system's foundations by converting the raw material warehouse and semi-finished goods warehouse into PI-hubs and by creating virtual-hubs near the production lines. In the third chapter, we built a simulation model of the factory based on the new approach, in which we performed runs with different parameters. In the model, we examined the material handling tasks performed by AGVs, depending on the intervals at which vehicles receive tasks. We compared the efficiency, performance, and waiting times available with the traditional and PI-based systems. The purpose of the model is to present a possible PI-based factory design. Finally, in the fifth chapter, we define future research directions and summarize the article's results.

Figure 1 π-container in supply chain and in intralogistics [5]

2 Physical Internet in intralogistics

The Physical Internet concept provides a solution to world sustainability from a social, environmental, and economic perspective. It addresses the drivers' cowboy lifestyle, which socially improves the current situation [6]. Through open PI hubs in the logistics network, it aims to allow drivers to change vehicles in these centers to stay as close as possible to their homes. From an environmental point of view, it intends to improve the current system from several angles. The creation of the π-container as one of the essential elements of PI takes into account the standardization of transport, the traceability of information, and environmental factors [7,8].

Furthermore, through interconnectivity – mentioned as one of the cornerstones of PI [9] – PI wants to reduce a large amount of air shipping globally and shorten routes through cooperation between companies. From an economic point of view, a PI-based system also takes essential steps, as the cost factor affecting companies is also essential for sustainability. In addition, the implementation of platooning technology can bring additional savings in the field of road freight transport [10].

Another important component is the PI-hub. In the logistics network, we can distinguish between fixed and virtual PI hubs. In the case of a fixed PI-hub, we mean infrastructural elements similar to traditional exchanges, which in turn differ in their design and functional operation from those existing today. The main difference is that these PI-hubs are available to all PI-users, and their internal design is characterized by connectivity, flexibility, automation, and sustainability, as exemplified in [2,3]. Another type of PI hub, the virtual PI-hubs with no building and other infrastructure support, aims to make the network more flexible by supplementing fixed PI-hubs. Virtual PI-hubs define a meeting point that provides an additional opportunity to perform transhipments and material handling in the system [11].

When we talk about Physical Internet-based logistics networks, it is important to define what components are required. In our previous research, we first defined the components based on extralogistics systems [4], and then we also determined their intralogistics versions [5]. The components are summarized in Figure 2.

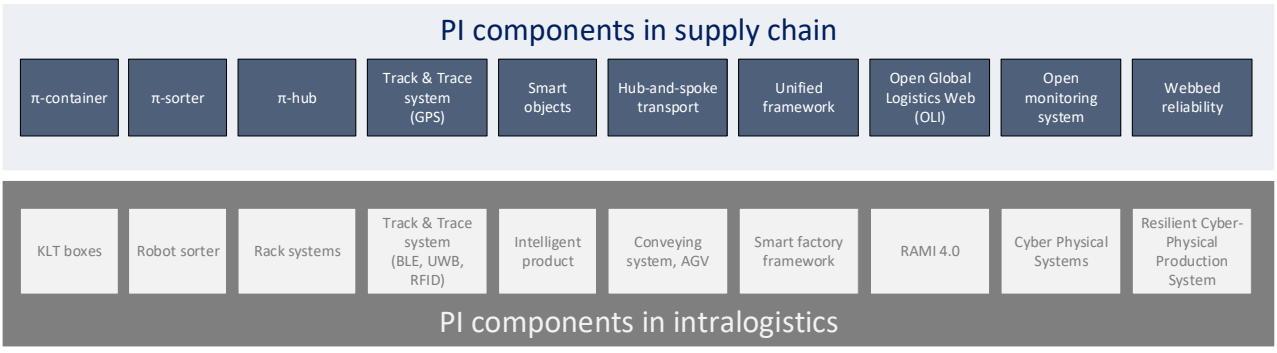

Figure 2 Physical Internet components in supply chain and intralogistics [10]

The components contain both physical elements and IT and control elements. For intralogistics systems, the physical elements include KLT boxes, robot sorters, pallet racking systems, and intelligent products and also include the conveyor system and AGV, the extralogistics conversion of hub-and-spoke. In the case of intralogistics, intelligent nodes play an important role for PI hubs, opening up new possibilities for local control of processes through centralized and decentralized concepts [12]. The IT components include the Track & Trace system, the

RAMI 4.0 for Industry 4.0 as a conversion of the open, global logistics web, and the Cyber-Physical Systems. Control components include the smart factory framework and the resilient Cyber-Physical Production System [5].

Ray Y. Zhong (2016) introduces a PI-based production management system (PIM2S), focusing on software perspectives such as system architecture and key services. He proposed a framework where real-time data from factories is collected using RFID technology. They also develop an interface service based on a middleware software concept that allows communicating with other systems through a standardized interface. Through a case study, they report on how PIM2S improves the tracking of real-time planning and scheduling [13]. In a similar approach, Ray Y. Zhong et al. (2016) proposed a PI-based manufacturing execution system (PIMES) for an intelligent workshop. A case study was conducted on a typical Mass-Customized company. The problem that indicated the implementation of PI is the frequent insertion and deletion of orders into production, which is difficult to control and follow even with the existence of an enterprise resource planning (ERP) system. By integrating PI, they create an omnipresent production environment. It has been shown that PI can support real-time decision making, automated statistics, and visualized production control and management [14].

Ray Y. Zhong et al. (2014) presented a PI-based shopfloor logistics management based on RFID-enabled Big Data methodology. They demonstrate the PI-based system's operation through a real manufacturing example, providing a basis for other RFID-compliant companies to build a forward-looking system. Methods for evaluating some KPI indicators are presented using the Big Data methodology. Their research draws attention to the widespread use of the Physical Internet and further explores its potential, highlighting real-time data-driven decision support [15]. Their previous research is developing a Big Data Analytics architecture based on information collected by RFID on the shop floor. One of the key basic PI elements, the π-container, has been expanded into a smart pallet [16].

An article by Lin I.-C. and Chen C.-Y. (2018) draws attention to the problem that currently all manufacturers produce a Physical Internet device with a unique specification, and compatibility between individual brands is very low. As a result, they present a platform system through a case study. This included an automatic product identification system, a tracking system, a finished product scanning, and packaging system, and an electronic shelf system. Expected benefits after deployment include reduced time and labor costs (~35% reduction), easier inventory and tracking through a smart shelving system, and improved machine capacity [17].

In [18], the authors focus on the production schedule as a classical combinatorial NP-difficult optimization problem and transform the traditional factory into a PI-based manufacturing system. The production schedule is divided into passive and initiating schedules depending on who initiates and directs the related decisions. They detailed that the technologies provided by Industry 4.0, such as IoT (Internet of Things), CPS (Cyber-physical system), cloud, and Big Data, provide the foundation for implementing the observation, computation, and service required for a PI-based system. The new system is called π -manufacturing system (π-MS). The π-MS system, with the new production environment, brings changes in the management of production processes and resources. It aims to implement intelligent tracking and precise identification. Interconnectivity, communication, standard protocols, and track&trace system as the Physical Internet's basic pillars also appear here. They compare their operations with current advanced manufacturing systems such as flexible manufacturing systems (FMS), agile manufacturing systems (AMS), and intelligent manufacturing systems (IMS). By comparison, they found that π-MS is more transparent, agile, flexible, and robust. The comparison is organized in Table 1. The π-MS implements the technological foundations of an intelligent, dynamic, interconnected, and flexible manufacturing environment.

Table 1 Comparison between π-MS and traditional manufacturing system [18]

	π-MS	**Traditional manufacturing system**
Production-driven pattern	Information-driven pattern	Energy-driven pattern
Response mode	Initiative respone	Passive respone
Production process control	Intensive pattern	Extensive pattern
Management style	Tranparent management	Black box management
Organizational structure	Flat structure	Hierarchical structure
Management dimension	Multi-dimensional (mesh network)	Two-dimension (manager and managed)
Decision-making approach	Autonomous interaction	Administrative assignment

In this paper, we present a simulation study on the possibility of using the Physical Internet in intralogistics. Based on the results presented in [15], we track with RFID all units in the production system. By continuously tracking the KLT boxes, we use location identification for planning and timestamp data for subsequent analyses. Like the π-MS presented in [17], we are developing new processes for resource management to implement a more efficient, agile, and flexible system with the new manufacturing environment. In the simulation, we examine the material handling tasks performed by AGVs. We then compare the traditional and PI-based manufacturing structures. The results of the comparison are detailed in the following sections.

3 Methods

In this section, we describe the PI-based manufacturing processes. As there are various scenarios on possible factory designs, we tried to focus on a basic layout to show the PI system's general applicability. The fundamental goal of the new structure is to break with the traditional operating logic (*TRAD*) and actualize an innovative manufacturing network system based on the Physical Internet (*PIHUB*).

3.1 Structure of the proposed model

In the model, we examine a simple manufacturing process with five different product routes. The basic idea comes from [8], on which Figure 3 is based. There are nine different transport relations in the traditional system depicted by the black arrows, each representing a different material handling activity. Traditional operating vehicles only transport between dedicated locations always on one route.

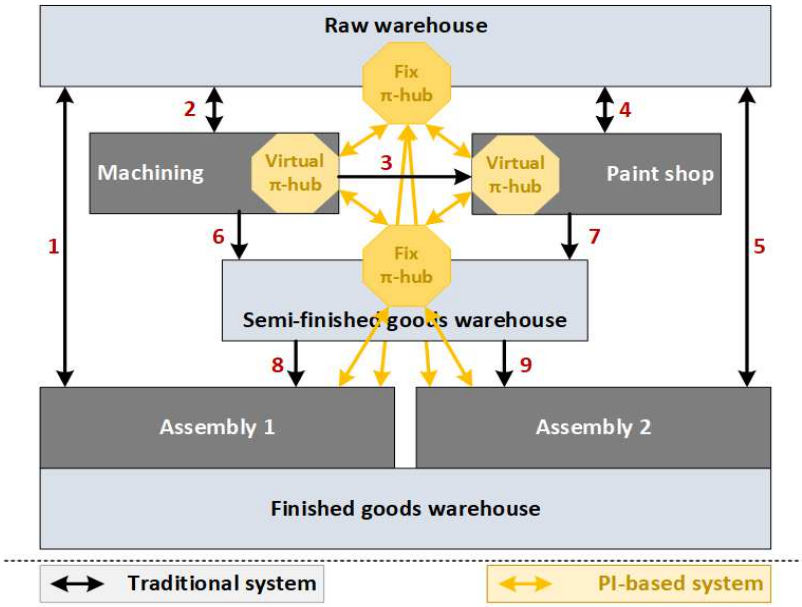

Figure 3 Simple factory design with PI implementation based on [5]

In contrast, the PI concept is to use all vehicles on all routes between all points. In Figure 2, PI implementation is also shown by the yellow arrows. Raw warehouse and semi-finished goods warehouse are transformed into fixed π-hubs so that every PI-user (vehicle) can access rack stores. Next to the machining area and the paint shop, we create virtual π-hubs. Thus, the KLT exchange can be executed similarly to an extralogistics PI system. Due to small distances in intralogistics, the locations of virtual π-hubs do not change in this factory. Unlike fixed π-hubs, virtual π-hubs do not have an infrastructural design like rack storage systems as fewer KLTs are in these areas than fixed π-hubs [5,11]. We need to model the flow of KLTs full of parts, and we also need to pay attention to the reverse logistics of the empty crates. This is the reason most routes are bidirectional. Routes (3) and (6)…(9) only flow in just one direction because only the raw warehouse expects empty KLT crates.

Creating a simulation environment of the presented model was essential for further examinations. The factory built in AnyLogic® Version 8.7.2 is shown in Figure 4. The coloured lines illustrate the five product routes. The gray and yellow ones show the two materials directly supplied from the raw warehouse to Assembly 1 and 2. The red and blue lines represent the first machined or painted materials which then are stored in the Semi-finished goods warehouse before being transported to Assembly 1 and 2. Green is the most complicated route in which the product is first machined, then painted after that stored in the Semi-finished goods warehouse and carried to Assembly 2. Nine AGVs carry out the transport tasks.

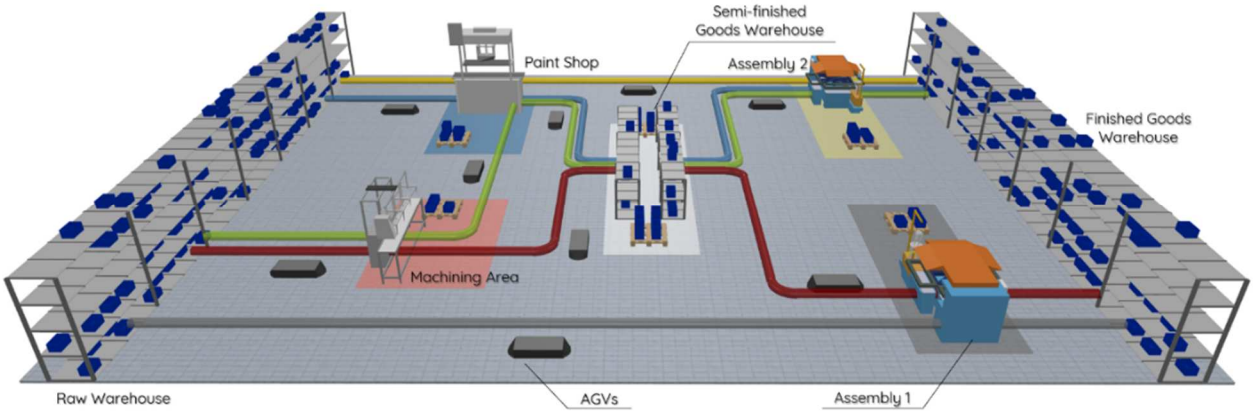

Figure 4 The 3D simulation model of the example factory

The AGVs are path-guided vehicles meaning they can only use straight paths similar to the lines shown in Figure 3. The usual load of an AGV in intralogistics systems is one EUR1 pallet. The modeled AGVs can carry four standard KLTs (400x600x200 mm) in one layer. Four layers can be stacked, resulting in a total of sixteen KLTs on one AGV. As the vehicles move surrounded by workers for safety reasons, the speed of the AGVs is 0.8 m/s [19]. The main inputs of the simulation are the time intervals that each KLT arrives in the raw warehouse. The KLTs are generated based on normal distribution taking into account the stochasticity of factory processes (Table 2). The time horizon of the simulation is 16 hours, starting from zero minutes to 960 minutes. Depending on the input parameters given according to Table 2, the minimum control event value is 5 minutes since KLTs arrive in the system average every 4.2 minutes. However, the maximum control time was set at 1 hour to ensure continuous operation of the factory. Accordingly, the generated KLTs wait for departure as every AGV launch will take action across a range of values from 5 min to 60 min.

Table 2 Time intervals between KLTs

Product type	Mean	Deviation
Product 1 (Gray)	3 min	1 min
Product 2 (Red)	4 min	2 min
Product 3 (Green)	6 min	1 min
Product 4 (Blue)	5 min	2 min
Product 5 (Yellow)	3 min	3 min

3.2 Solution methodology

Discrete Event Simulation (DES) is the most common method of modeling microsystems such as intralogistics networks. A sequence of events models the process in which the observed passive entities (in our case, the KLT compartments) flow in a predetermined order. This simulation method is often used alongside Agent-Based Modeling (ABM), which consists of active objects such as AGVs. These active objects can communicate with each other and can interact with the environment. We can combine the two simulation methods and build automatic systems. We used the Process Modeling Library (version 8.0.5) and the Material Handling Library (version 8.3.0) of the AnyLogic simulation software to create the traditional and the PI-based intralogistics system. We first present the traditional version structure and then describe the changes we made to develop the PI-based version.

There are three agents in the model. The first one is the KLT, the second one is the UNIT which contains the given number of KLTs transported together, and the third one is the AGV which transports the units. Each of the five product routes has a Source object which generates the KLTs at the given time intervals based on Table 2. To initialize the model, we insert KLTs from all product type at the beginning of the simulation. After each source object, we insert a queue where the created KLTs are waiting for delivery. The queue objects do not have capacity limitations. As mentioned, the KLTs wait until the AGV launch. Until then, the process is held back by a Hold object. The hold objects are initially blocked and set to allow through a specified number of agents before blocking the process again. A Batch object follows the hold objects. This object is responsible for arranging the given number of KLTs into the new UNIT agent.

After batching the KLTs, the MoveByTransporter block transports the unit to the specified destination where the unit is unbatched by the UnBatch object. One Transporter Fleet is dedicated for each relation (9 fleets each with one AGV), and the vehicles can only transport between the predefined locations. In case it is the final destination of the KLTs, they exit the model by a Sink object. Otherwise, at the assembly lines, machining, and painting areas, the KLTs wait in a queue before entering the Delay objects. After the delay, a Split object creates a new KLT agent representing the crate full of finished or semi-finished goods. This way both the empty and the full crates stay in the model. These full crates exit from the model at the assembly lines, but from the machining and

painting areas, they enter a queue object, and from there, they are transported to the next station. The empty KLTs continue their path into a queue so the AGVs can transport them back them to the raw warehouse. These forwarding and reverse transports are modeled by the same process already explained, beginning with the queue object and finishing with the sink object. Figure 5 shows the first route (from the raw warehouse to assembly 1 and back). As the transporting method is the same for all routes we used a flowchart block that is equivalent to a function in which we only need to change each route's parameters. This flowchart block is shown in Figure 6.

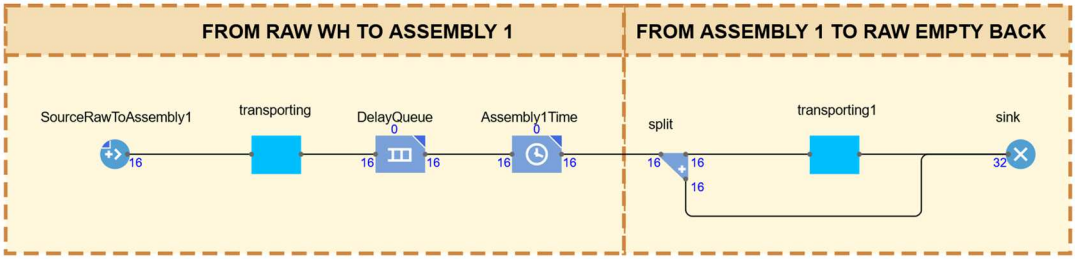

Figure 5 AnyLogic flowchart of first route

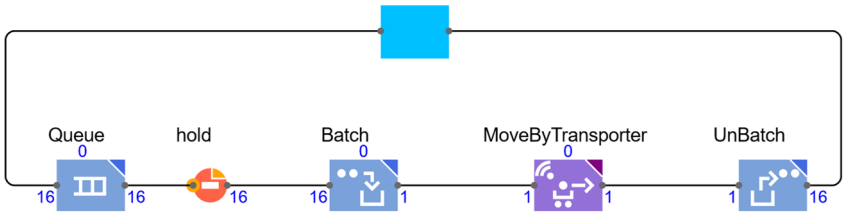

Figure 6 Transporting flowchart block

A control event guide the *hold* object. The control event occurs in the first run every 5 minutes, in the second run every 10 minutes, in the third run every 15 minutes, and so on up to 60 minutes. The event logs the number of agents waiting in all queues at the moment. The model examines 13 waiting lines. Four from the raw warehouse to the machining, painting, and the two assembly areas and also four for the empty KLTs from these areas back to the raw warehouse. One from the machining to the painting area and two from the machining and painting areas to the semi-finished warehouse. It is unnecessary to return the empty KLT from a semi-finished warehouse, either between the machining or painting areas. The last two lines are from the semi-finished warehouse to the assembly line 1 and 2. For each relation, the software algorithm compares the number of KLTs waiting for transport, if there are any. For instance, on the first route where the KLTs move from the raw warehouse to assembly 1 and then the empty KLTs are transported back, the event will unblock the direction with more KLTs waiting in line. If there is no KLT waiting, then this AGV will not be launched. If a route is not bidirectional, then the waiting line is compared to zero. To execute the transportation with the corresponding number of KLTs, before unblocking the hold objects, we need to set the unit's batch size to be the same amount as the number of agents allowed through the hold object. If the chosen direction has less than sixteen KLTs in the queue (capacity of the AGV), we set the hold and batch objects' parameters to the number of the waiting KLTs. Otherwise, we set it to sixteen. This method runs for every relation launching the AGVs for each transportation. The model stores the size of the batches in an external database. After AGVs finished the transport, they stay where they are. In this scenario, on a relation, only one AGV transports in only one direction per launch. It means that if a bidirectional relation (e.g., Raw WH to Assembly 1 and back) has KLTs waiting on both sides, and a not bidirectional relation (e.g., Semi-finished WH to Assembly 1) has zero KLTs, then at least one AGV will be unassigned.

We do not modify the model's main structure in the PI-based system but change two fundamental logic. One Transporter Fleet executes the transports with 9 AGVs. AGVs do not only travel in fixed connections so that all vehicles can travel from any location. The control event also operates differently. Instead of checking the relations separately, it lists the thirteen queue lines in a descending order based on the number of KLTs waiting. As there are nine transporters, they will transport the first nine queues with the highest number of KLTs. The model unblocks the "hold" objects, and the batch sizes are set by the same method as explained before. When a transporter does not have a task on one path, it can move to another relation. The main difference is shown in Figure 7.

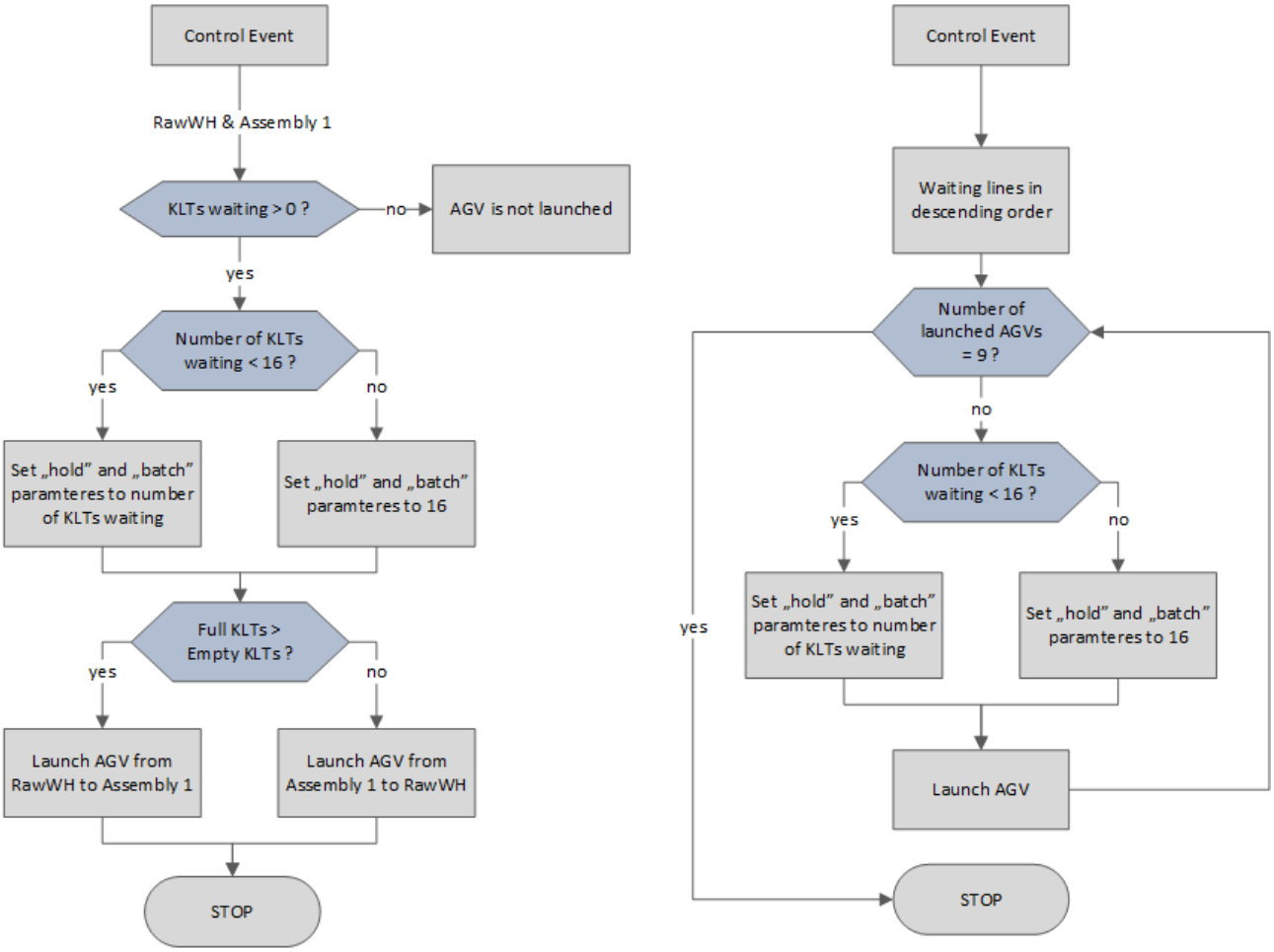

Figure 7 Proccess Chain of traditional (left) and PI-based (right) system

4 Results and discussion

In this chapter, we detail the simulation results of the presented Physical Internet-based model. In the simulation studies, the input data for the arrival of KLTs were always the same, according to Table 2. We changed the event's value that controls the scheduling of AGVs from 5 min to 60 min, which declared how often AGVs receive new tasks. For each different interval, we run the simulation five times for 16 hours on both models. Thus, resulting a total of 12 cases, we performed five runs in each case for the given structure, so we performed a total of 120 simulations. In the study, we compared the two algorithms (traditional and PI-based) presented in Chapter 3.2. In comparison, we determine some Key Performance Indicators (KPIs) based on [20] and [10]. We evaluate the results from two perspectives: we analyze the AGVs and KLTs. For the formulas used for KPIs, Table 3 shows the general notations compiled.

Table 3 Mathematical notation

Parameter	Description
V	set of vehicles (AGVs)
N	set of KLTs
$s_k(i,j)$	length of the kth transport route between points (i,j)
$C_{free,k}$	free capacity in loading units during the kth transport task
C_k	capacity in loading units during the kth transport task
$\Delta t\ (waiting)$	length of a KLT wait time until an AGV picks up to move
M_{KLT}	total number of KLTs moved between examined locations
V_{busy}	total time an AGV was busy
t_{shift}	time of the shift used in the simulation (16 hour)

First, we analyze the KPIs for AGVs. The first indicator examined is ineffectiveness, which can be calculated based on [10] as follows:

$$Ineffectiveness = \sum_{k=1}^{V} \frac{C_{free,k} \cdot s_k(i,j)}{C_k \cdot s_k(i,j)} (\%) \qquad (1)$$

We determined the product of the capacity left free and the distance traveled by the AGVs. The value obtained was then divided by the theoretical worst case, i.e., the product of the empty AGV and the same path. We calculate this for each movement of each AGV for both traditional and PI-based manufacturing structures. The value of inefficiency can be between 0% and 100%. The ineffectiveness values of the runs from 5 min to 60 min are shown in Figure 8.

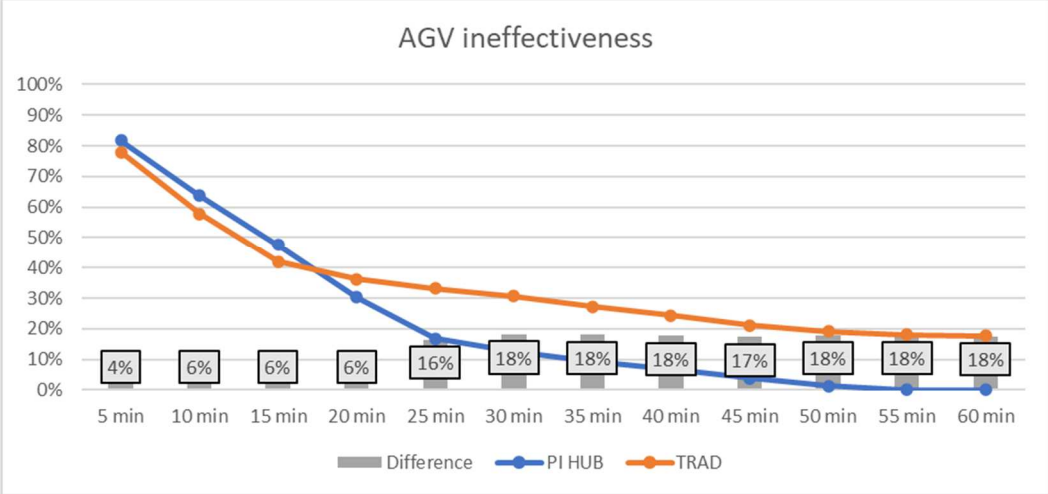

Figure 8 Ineffectiveness of AGVs for PI-based and traditional structures

Based on ineffectiveness, the lower its value, the better the system works. Accordingly, we can see that PI-based manufacturing can operate more efficiently in all cases. The initial high value is related to the normal distribution parameters used for KLT generation, as KLTs arrive in the system too infrequently for a 5,10,15-minute start. At higher event times, enough KLT can already flow in the system for a PI-based system to operate efficiently. The less frequently (at longer time intervals) AGVs are given a task, the inefficiency decreases. In the figure, the gray bars show the degree of difference between PI-based and traditional systems.

The next examined indicator is the material handling performance, which was calculated as follows:

$$Performance = \sum_{l=1}^{N} \frac{M_{KLT} \cdot s_k(i,j)}{t_{shift}} \left(\frac{KLT \cdot meter}{hour}\right) \qquad (2)$$

According to the formula, we multiplied the distance traveled during movement by the number of pieces moved for each unit. The product was then divided by the length of the study period, which was 16 hours. We calculate this for each KLT moved. The results for the cases studied from 5 minutes to 60 minutes are illustrated in Figure 8.

Based on Figure 9, there is no significant difference in material handling performance between the two structures (*PIHUB* or *TRAD*). Except for low control event values (5,10,15 minutes), the PI-based system achieved higher material handling performance. There is a decrease in material handling performance for larger control events. With a higher control value, AGVs deliver KLTs less often. Although the utilization of the AGV increases, as shown in Figure 8, it cannot result in higher performance due to the maximum capacity limiting condition (16 KLTs/AGV).

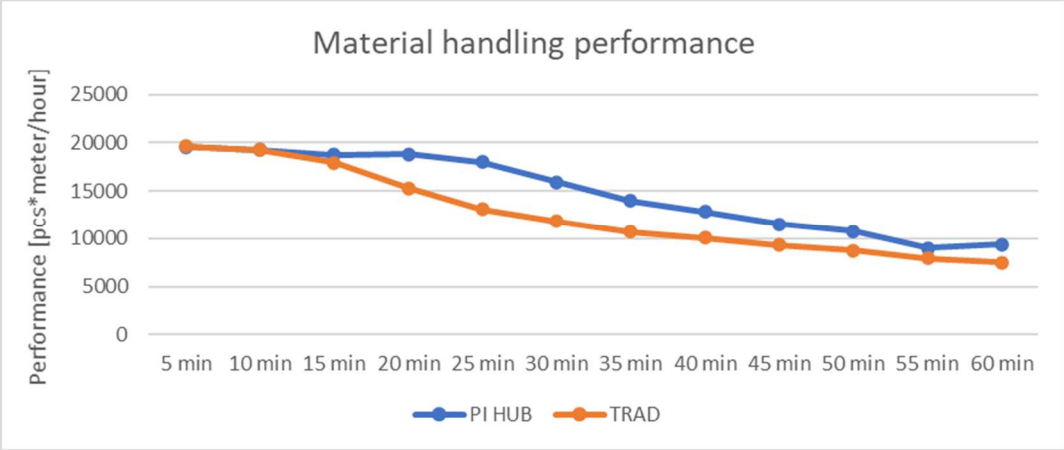

Figure 9 Material handling performance of AGVs for PI-based and traditional structures

The next two parameters analyze the KLTs. The first illustrates the intensity values for each relation, which were calculated as follows:

$$Intensity = \frac{M_{KLT}}{t_{shift}} \left(\frac{KLT}{hour}\right) \quad (3)$$

We divided the total number of KLTs delivered in the examined time horizon by the value of the examined time horizon. The result obtained is shown in Figure 10.

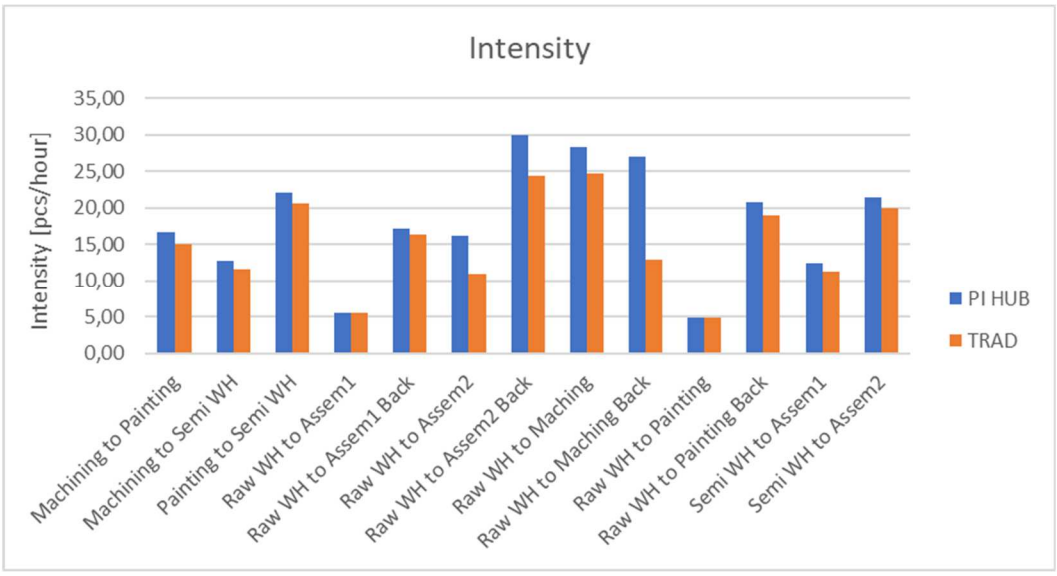

Figure 10 Intensity for each relation

Stochastic processes induce the discrepancies shown in Figure 10. The purpose of this diagram is to illustrate the significant intensity differences that appear in different directions. In the case of a traditional factory structure, where the AGV was assigned to a given direction, the AGVs cannot compensate for the hectic process. In the Physical Internet-based system, where, in addition to making KLTs intelligent, the PI hubs create an open system and flexibility. With this novel PI-based system, handling the differences (shown in Figure 9) is less problematic. AGVs manage the entire system together to decide which next delivery task to perform.

Finally, we examined the waiting time of the KLTs, the time that the KLT waits for the AGV to complete the moving task. The calculation of the waiting time was performed as follows:

$$Waiting\ time = \frac{\sum_{l=1}^{N} \Delta t\ (waiting)}{N}\ (min) \quad (4)$$

For the given system, we determined the average waiting time. Based on the formula, we determine the waiting time for each KLT, and after summarizing, we divided it by the number of KLT boxes (Figure 11).

Figure 11 Waiting time of KLTs for PI-based and traditional structures

We can achieve slightly better values in the traditional system in waiting time, so the KLT has to wait less to move as soon as an AGV starts to pick up for it. The goal of the PI-based system is sustainability, which in this case can be related to balanced operation. In a PI-based system, to minimize the number of empty turns, the KLT must wait longer for larger volumes to accumulate. In the traditional system, it is not decided at the system level which unit should be delivered by the AGVs. According to the simulations, on average ~37% more KLTs remain in the traditional system, so the conventional operation is on average 37% more congested. Also, in the traditional case, the required distance traveled is usually shorter, as the AGV only travels back and forth on one road section. Therefore we can get a slightly longer waiting time for a PI-based system to achieve a more sustainable and balanced operation.

Based on the results, we can say that the Physical Internet integration is also worthwhile in terms of intralogistics systems. We expected the available improvement to be lower than an extralogistics system, but the new structure and mindset may offer many new opportunities compared to traditional systems. The creation of a PI-based intralogistics system supports the achievement of the sustainability, flexibility, and higher efficiency needed for the future's challenges.

5 Conclusion

The Physical Internet as a future logistics system model is gaining more and more interest among academics. Although publications mostly approach the supply chain side, studies on intralogistics applicability are beginning to occur. In our opinion, the integration of the Physical Internet into intralogistics systems is useful. In this article, we created an innovative PI-based factory structure. The warehouses were converted to PI-hubs, and virtual PI hubs were placed near the two manufacturing elements (machining and painting) to create a more flexible structure. The π-containers were realized with KLTs, and AGVs performed movements. AGVs are assigned tasks driven by a control event. We created the model in an AnyLogic simulation environment. During the simulation runs, we examined the results obtained by changing the control event's time value from 5 min to 60 min. The results were compared based on the traditional and PI-based systems. During the evaluation, we determined the values of ineffectiveness, performance, intensity, and waiting time. In the case of ineffectiveness, the maximum value is 100%, in the case of the other parameters the maximum cannot be determined, their value depends on the generated input data and the operating logic. The main result is that the PI-based system's inefficiency is lower at higher control events to achieve more efficient and flexible operation. Furthermore, in the case of waiting time, the traditional system provides better operation, but the system will be less sustainable and balanced.

Further research and development are also needed, such as examining the functional operation of the appearing warehouse elements. By creating a more accurate schedule, the system could also be further developed, including emerging technologies such as Big data or machine learning.

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SIMULATION MODELLING AND ANALYSIS FOR IMPROVING THE PERFORMANCE OF PRODUCTION CASE STUDY: JORDANIAN VEHICLES MANUFACTURING COMPANY

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Keywords: ARENA Simulation, production modelling, production lines, process utilisation
Abstract: Modelling and analysing production lines are crucial for the research community and designers interested in increasing production utilisation and reducing costs. This paper aims to model and analyse a real production process of a Jordanian vehicles manufacturing company and improve production line resource utilisation using ARENA simulation software. The methodology used is simulation modelling to develop a new production line design. Performance measures are obtained from data given by the company management and direct observation of the production line. A suggested modified Arena simulation model is developed for the production line processes based on the collected data. Verification and validation analysis of the proposed model is done. Results show that the proposed model's performance is better than the current one in terms of; overall total processing time, the overall waiting time, the overall work in process, and the overall utilisation.

1 Introduction

Simulation is the imitation of the processes of a real-world system in generating an artificial history to draw inferences concerning the operating characteristics of the real system [1]. Simulation modelling is used to optimise the performance of a real-world system with low cost, secure and fast analysis with many different system configurations [2]. Simulation software programs are used to simulate the process, which brings the power of modelling and simulation to business process improvement. It is considered a powerful tool to help demonstrate, predict, and measure system strategies for effective, efficient, and optimised performance.

Manufacturing provides one of the most important applications of simulation. Especially in studying and analysing the production lines to determine how well production facilities are being used. According to Fauci et al. [3], simulation of production lines is such a powerful tool in obtaining the performance measures in situations where analytical techniques are either difficult or impossible to use.

It is proposed in [4] that, a semantic conceptualisation to describe an organised Sensitive Business Processes within a new Business Process Meta-model for Knowledge Identification (BPM4KI). The proposed model covered all the aspects including the organisational, functional, informational, behavioral, knowledge, and intentional perspectives. The proposed model is semantically rich and well based on «core» domain ontologies.

A decision-making model for applying for the knowledge transfer support effectively in manufacturing enterprises using the GMDH approach is discussed in [5], The model [5] focused on several knowledge workers characteristics within manufacturing companies based on a survey from 119 Polish enterprises.

A process-based knowledge management framework to analyse knowledge flow employing a two-phase analysis: knowledge-flow analysis and process analysis is proposed in [6]. The results showed that the proposed knowledge-flow model was useful in recognising the relationship between the manufacturing processes and knowledge where the diagram acts as a knowledge mediator amongst

a worker and the associated successor. Patalas et al. [7] presented the ExKnowIT information system that is supporting the expert knowledge eliciting for successful IT projects. The model consisted of (1) the experts' identification for successful information technology projects, (2) the expert knowledge eliciting on finished IT projects, (3) the expert knowledge according to finished information technology projects, (4) the Group Method for Data Handling (GMDH) algorithm, (5) manager selection new knowledge for a new information technology project.

A model for utilising, managing, and collecting integrated engineering outputs within the life-cycle process of the product is proposed in [8], where the model output acquisition was designed for assembling outputs without further efforts when time outputs were registered, given that with the project schedule. As revision happens within the project period, the revision is transferred to the corresponding process through the Engineering Change Order process. The results showed that the system in the electric transformer EPC project performing usability, concurrent-multiple projects, and an accumulating outputs degree that comprises process accuracy and revision history was enhanced about the PDM (Product Data Management) system used previously.

The purpose of this research study is to apply ARENA software to simulate, evaluate and improve the performance of a production line as a real case study at one Jordanian vehicle manufacturing company. Actual data is collected and analysed for each workstation, including processing time, the overall waiting time, the overall work in process, and the overall utilisation. Arena software is chosen for this study due to its modelling flexibility and ease of use. It provides building models for many scenarios and options to document, visualise, and demonstrate the dynamics of a process with animation. It also predicted system performance based on key metrics such as throughput, cycle times, and utilisations.

Moreover, it identifies process bottlenecks such as queue build-ups and overutilisation of resources [9]. Many scientific papers have shown that simulation is an effective tool that helps solve many industry problems [10]. In this paper, problem description and methodology are introduced in Section 2. The proposed production line model is presented in Section 3. Results and discussion are demonstrated in Section 4. Finally, the conclusion and recommendations are summarised in Section 5.

2 Problem description and research methodology

After investigating and analysing the current process flow of the production lines for producing the vehicle, a new production line layout is proposed based on simulation modelling and choosing the appropriate lean manufacturing tools to eliminate the non-added value activities. The production processes consist of 13 workstations that contain many activities starting by preparing the chassis, grinding the Armor, fitting hinges, releasing the door then fitting all brackets and spacers, painting process, preparing the floor, and fitting some electrical and mechanical parts, trimming process plus fitting accessories and finally, painting. To achieve the previous research objective, a compression study between the current process flows versus the future process flow regarding total time, waiting time, several works in process, and resource utilisation. The simulation modelling research methodology is proposed and illustrated in Figure 1. The full current process is shown in Figure 2, where a Value Stream Map (VSM) of the existing production line is built as an experimental model by placing modules that represent processes or logic. The VSM shows how these modules are connected and joined together to specify the flow of entities within the company's production lines [11]. This requires the design and development of a new production line that has improved future productivity of all aspects of vehicle production.

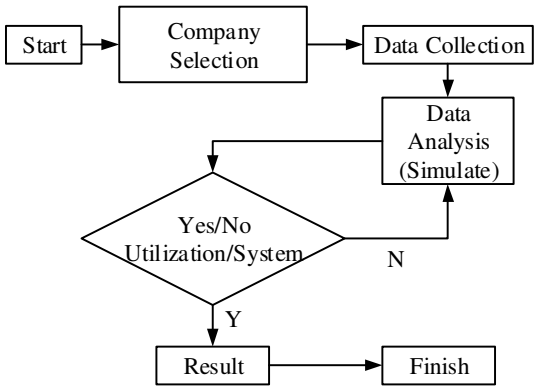

Figure 1 Schematic presentation of the research methodology

2.1 Company selection

The considered vehicles manufacturing company is a Jordanian company in partnership with other companies. It was established to develop, manufacture, and market special and protected vehicles worldwide for international governmental and non-governmental organisations. The company is considered a prime pillar in the local automotive and industrial cluster. It is a customer-driven company, where the production strategy followed by the company is "male to order" while ensuring the best operational practices and the highest armouring standards [12]. The vehicles that the company produces are operated in more than 30 countries all over the world. Their vision is to be a world-class manufacturer of light vehicles, and their mission is to manufacture and sell high-quality protected and special purpose light vehicles and their components for the law enforcement, security, and civilian markets worldwide, fulfilling customers' requirements [12]. The facility is located in Jordan, and it encompasses eight production lines, a well-equipped off-line production area, warehouses, and the administration.

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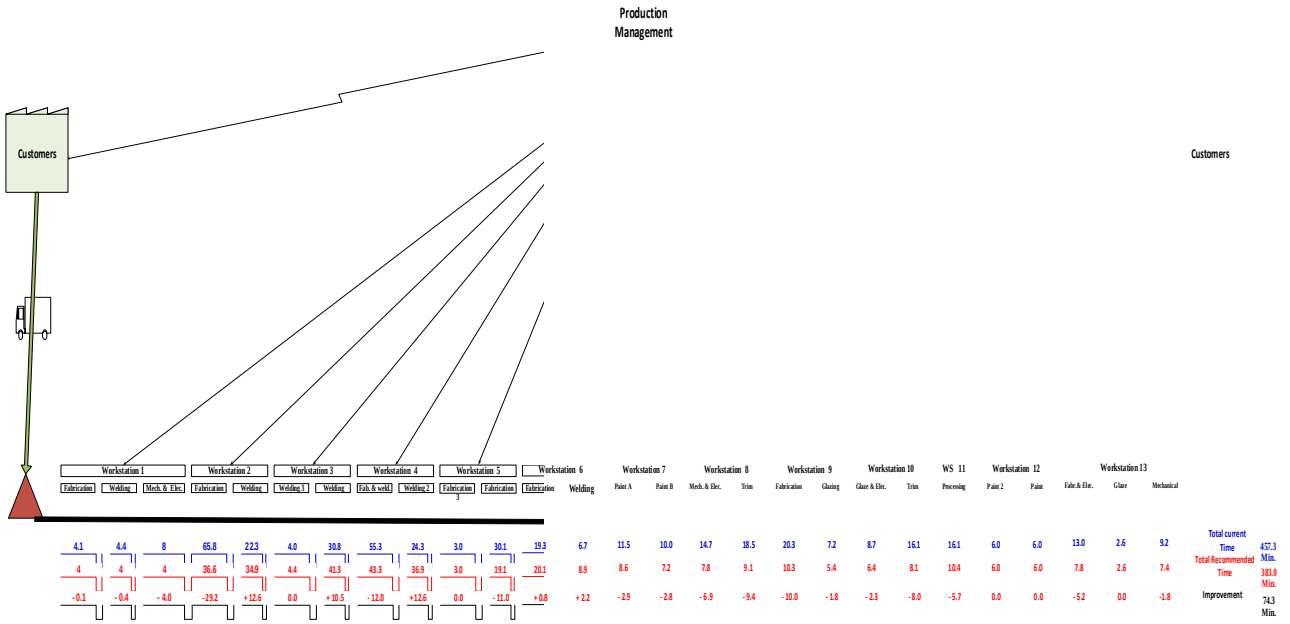

Figure 2 Value Stream Mapping (VSM) of the current production processes for producing the vehicle

2.2 Data gathering and data modules

Actual operational data has been collected by visiting the factory several times and observing the production line to understand the interrelations between activities and realise the structural process constraints. Performance measures are obtained from data given by the company management. The collected data is well planned in targeting key data contemplate the simulation model objectives such as total processes time, waiting time, resources utilisation, and the number of process works.

A set of modelling assumptions are set according to the system constraints related to the process type, workforce size, and the entity's movement sequence between the stations. In the current and proposed production line simulation, three data modules are used, the entity data module, which is the vehicle, the resource data module in the simulation system for all workstations. Finally, the station data module defines a set of stations corresponding to a physical or logical location where processing occurs.

3 Proposed production line model

According to follow process flowchart within the production workstations, the ARENA flow model was constructed as shown in Figure 3. Sub-model was used to facilitate handling of simulation flow model [13]. A sample for workstation No. 1 in the current model and the proposed model is shown in Figure 4 and Figure 5, respectively. To improve resource utilisation, the current layout of the company's production line has been developed. Figure 6 shows the proposed production line model. It reduces the total processing time and reduces the waiting time, thus making the production line more efficient.

3.1 Verification and validation

The verification step consists of verifying that the computer program performs properly. In other words, is the computer program the exact translation of the knowledge model? Usually, with complex systems, it is difficult, if not impossible, to translate a model successfully without a good deal with debugging. During the verification phase of the simulation model following steps have been implemented: check that the computer program does what it is supposed to. Use sound programming techniques. Check the output for reasonableness and view animations [14].

After the verification stage, validation is so important to be sure that the model is an accurate representation of the real system. Validation is usually performing through the calibration of the model. It consists of an iterative process of comparing the model with the system and adjusting parameters. Of course, if the validation fails, the data collected and/or the knowledge model can be reconsidered. Validation steps include: Check that the model accurately reflects the real system. Compare model output to real system output. Involve system experts and model users throughout development and explicitly state and verify all model assumptions [15].

Validation was checked with many replications to ensure the behaviour of distributions that were used. Table 1 shows the validation results. In Table 1, the comparison between observed total time and total simulated time for five different number of replications, including long-term

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simulation. As a result, the simulation model of 22 vehicles was valid and mimic the behaviour of a real system.

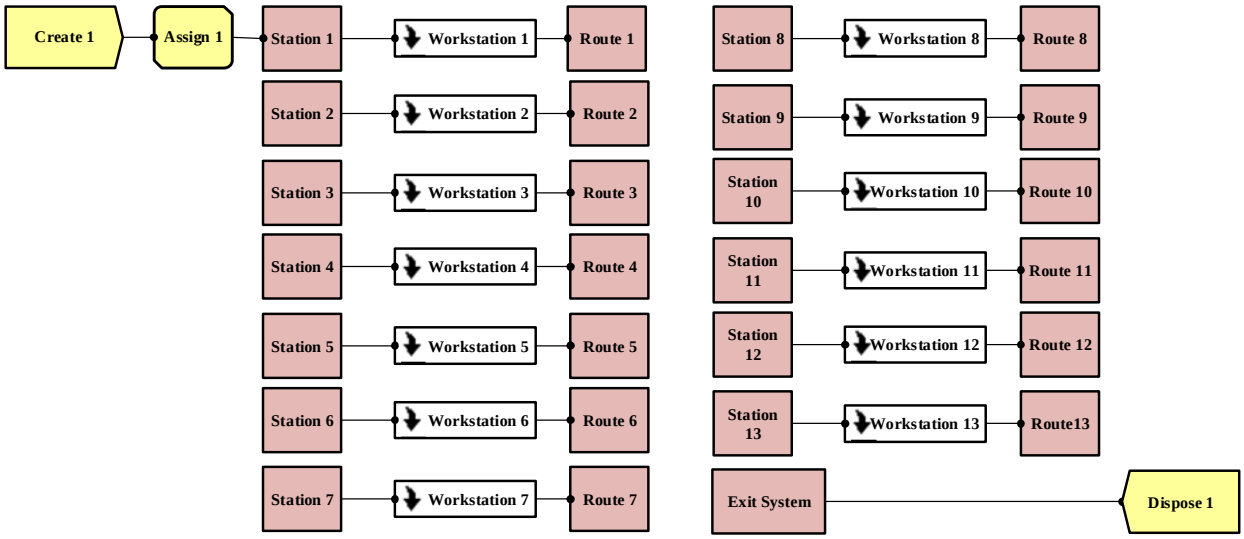

Figure 3 Simulation model for vehicle production line

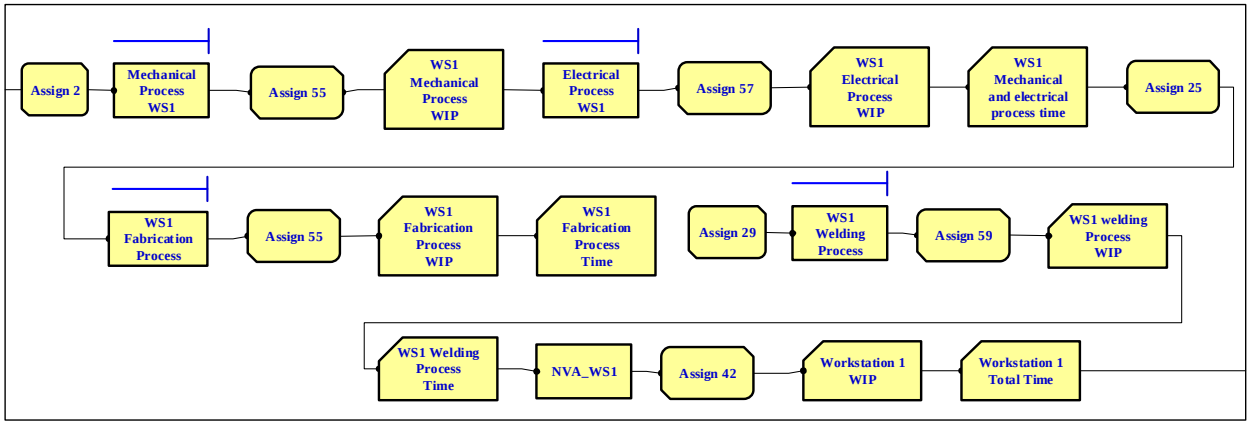

Figure 4 Workstation No. 1 – the current model

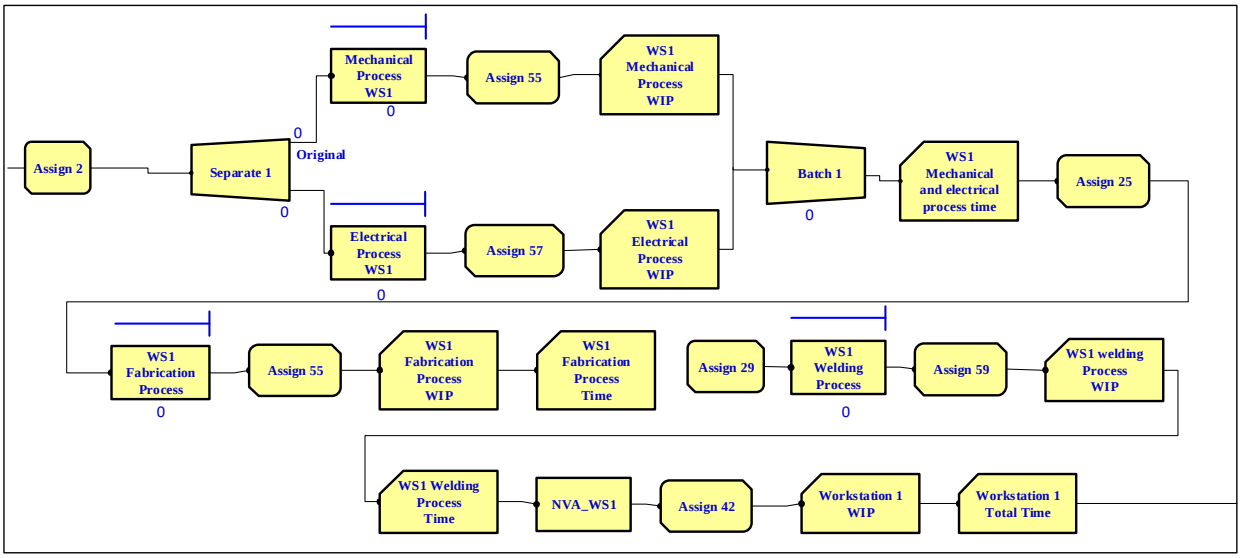

Figure 5 Workstation No. 1 – the proposed model

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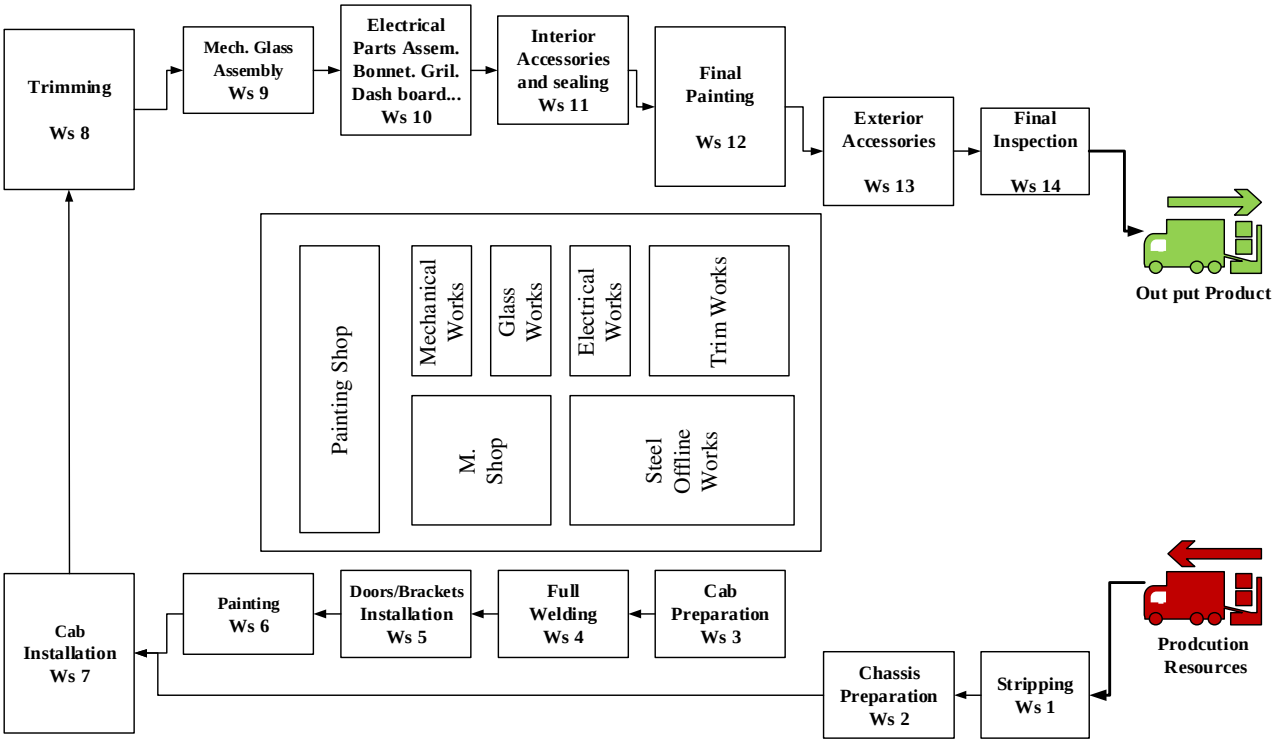

Figure 6 Proposed process flowchart for vehicle production line

Table 1 Validation Analysis

Total observed time (Hours)	Total simulated time in hours, under different number of replications				
	R = 1	R = 2	R = 5	R = 10	R =25
456	456.39	456.40	456.42	456.53	456.50

4 Results and discussion

Comparing the status (as-is) of the current follow chart and the current simulation model with (to-be) status, it is found that some processes within the same workstation can be implemented in a parallel manner rather than the current series flow to improve the resources utilisation.

4.1 Total processing time comparison

The total accumulated processing time was reduced from (457.3 hours) to (383.0 hours) in the proposed production line layout model. Figure 7 demonstrates how processing time is distributed across all workstations. The WS3 welding process 3, processes in workstations 4, and workstations 6 have processing total time higher than the current model.

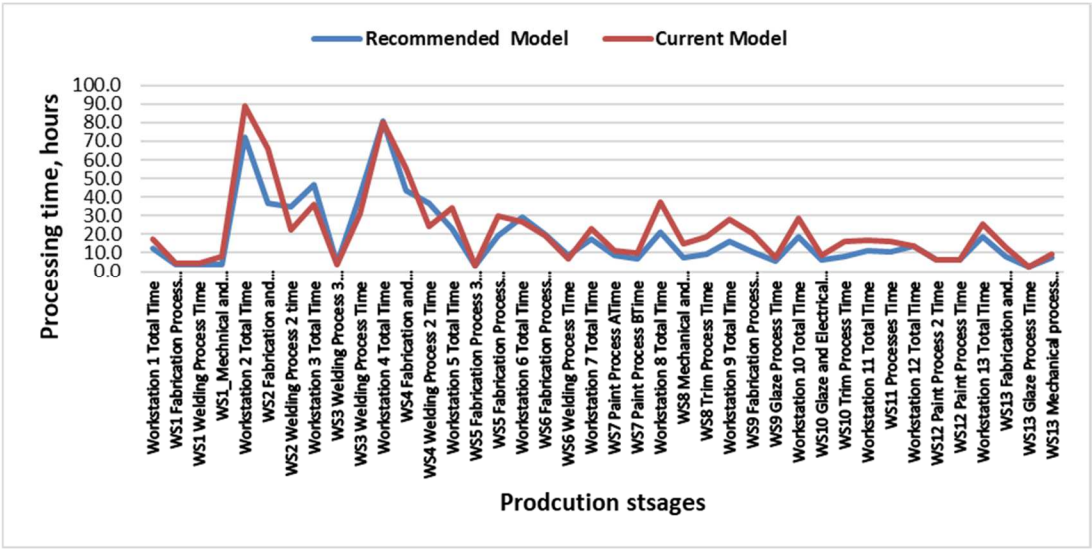

Figure 7 Total processing time comparison between current and recommended model

4.2 Waiting time comparison

The waiting time comparison between the current model and the proposed model for all queue lines in the ABC production line, as can be seen from Figure 8, that 29 out of 47 queue lines have waiting time in the proposed model lower than the current model. At the same time, the remaining queue lines have similar waiting times in both models.

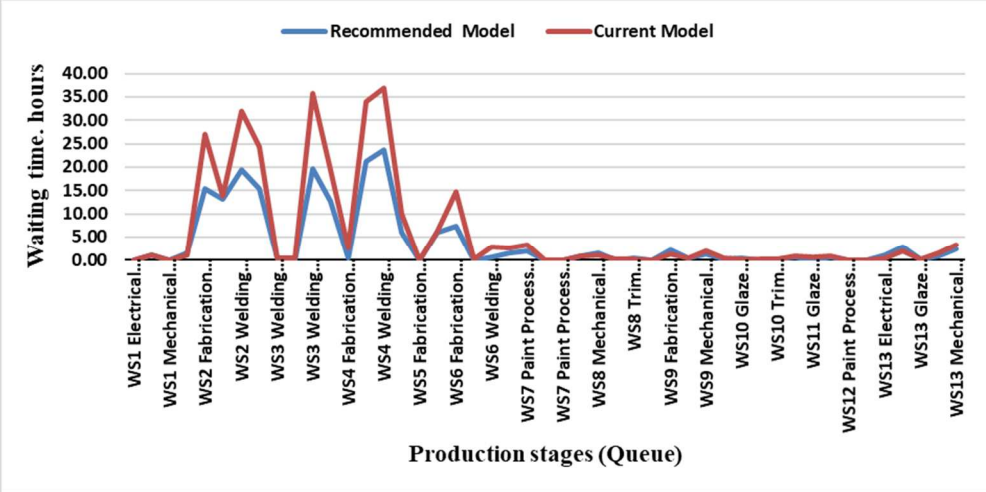

Figure 8 Waiting time comparison between current and recommended model.

4.3 Comparison of WIP level

Although, as shown in Figure 9, there are an oscillating discrepancy between the work in process (WIP) quantity levels in the two models. When the total average (WIP) level for both models is compared, the findings are identical.

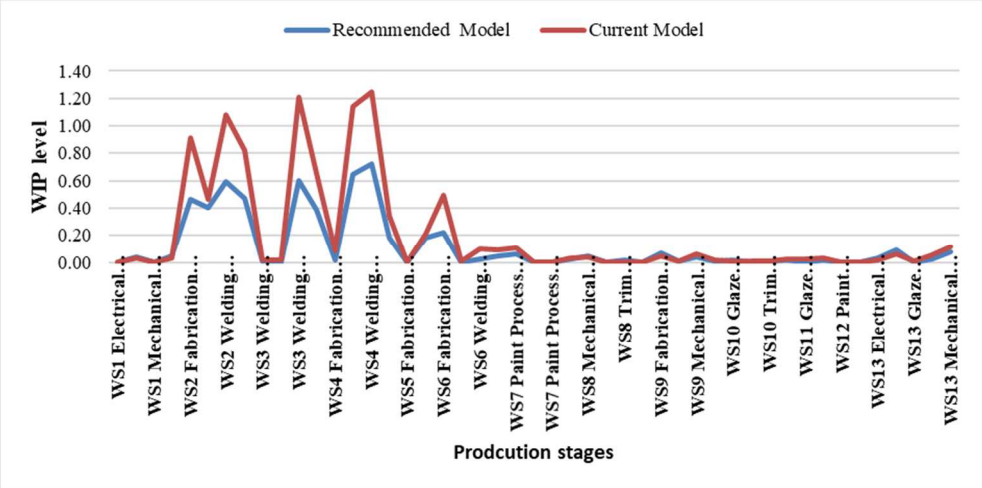

Figure 9 Quantity of WIP comparison between current and recommended model

4.4 Resource's utilisation

Figure 10 represents schedule utilisation for resources (workers) in the current model, with schedule utilisation ranging from 9.18 percent to 53.56 percent. Welding worker No. 1 (Weld 1) has the highest schedule utilisation (equals 53.56 percent) followed by fabrication worker No. 19 (Fab 19), which has a value of 45.91 percent. The lowest schedule utilisation for fabrication worker No. 7 (Fab 7) with schedules utilisation is equal to 9.18 percent.

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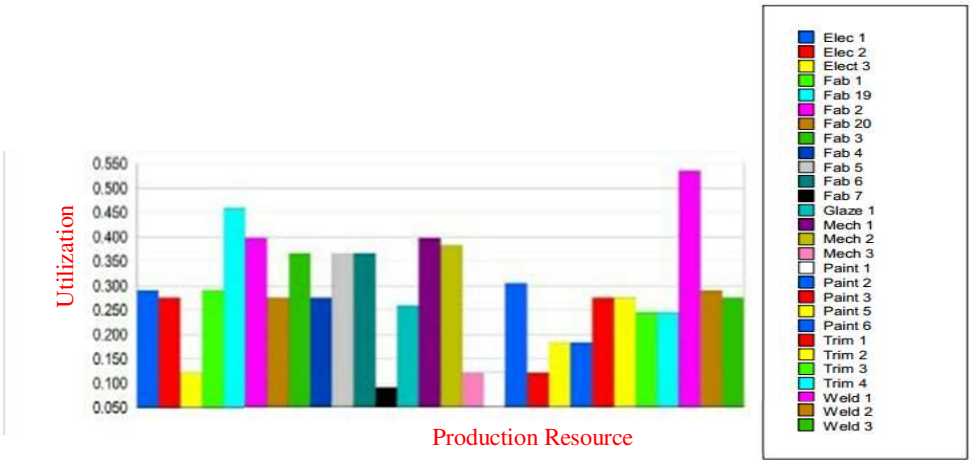

Figure 10 Utilisation of resource – the current model

In the proposed model, the schedule utilisation for resources (workers) ranged between 10.12 percent and 59.02 percent, as shown in Figure 11. Welding worker No. 1 (Weld 1) has the highest utilisation (equals 59.02 percent) followed by fabrication worker No. 19 (Fab 19), which has a value of 50.59 percent. Whereas the lowest schedule utilisation for fabrication worker No. 7 (Fab 7) with schedules utilisation equal to 10.12 percent.

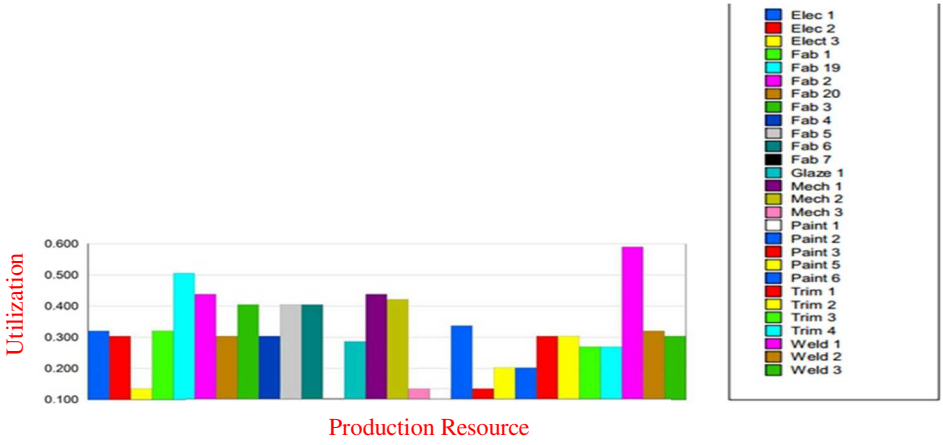

Figure 11 Utilisation of resource – the recommended model

As shown in Table 2, a comparison of schedule utilisation for the proposed model and the current model reveals that overall utilisation for all workers has improved. Fabrication worker No. 7 (Fab 7) improved by 0.94 percent, while welding worker No. 1 improved by 5.46 percent (Weld 1).

5 Conclusions

In this paper, a production line of a Jordanian vehicle manufacturing company was efficiently simulated using Arena, to improve and develop a new production line design. Processing time, waiting time, WIP level, and utilisation of capacity have all been used as a performance indicator. After completing this research, verifying, and validating the model and results. Several outcomes were discovered, including the following.

- According to the results, the proposed simulation model has achieved a significant reduction in both total and waiting times. It is also shown that the proposed model has a slightly lower WIP level than the current model.
- Moreover, the overall resource utilisation in the proposed model is better than the current model by approximately 10.21%.
- By following the simulation methodology presented in this paper, general production lines can be analysed, regardless of size, used technology, variation, or the multiplicity of their products, by following the simulation methodology presented in this paper, not only that but also systems production services can be analysed in the same manner, implying that the simulation system presented here can be used in the analysis of all

production lines, whether it is configured in a serial, parallel or hybrid structure.

Table 2 Schedule Utilization Comparison

Resource Name	Utilisation (%)		Improvement	
	Proposed	Current	Amount (%)	Rate (%)
Elec 1	32.04	29.07	2.97	10.22
Elec 2	30.35	27.54	2.81	10.20
Elec 3	13.49	12.24	1.25	10.21
Fab 1	32.04	29.07	2.97	10.22
Fab 19	50.59	45.91	4.68	10.19
Fab 2	43.84	39.78	4.06	10.21
Fab 20	30.35	27.54	2.81	10.20
Fab 3	40.47	36.72	3.75	10.21
Fab 4	30.35	27.54	2.81	10.20
Fab 5	40.47	36.72	3.75	10.21
Fab 6	40.47	36.72	3.75	10.21
Fab 7	10.12	9.18	0.94	10.24
Glaze 1	28.67	26.01	2.66	10.23
Mech 1	43.84	39.78	4.06	10.21
Mech 2	42.16	38.25	3.91	10.22
Mech 3	13.49	12.24	1.25	10.21
Paint 1	13.49	12.24	1.25	10.21
Paint 2	33.73	30.60	3.13	10.23
Paint 3	13.49	12.24	1.25	10.21
Paint 5	20.24	18.36	1.88	10.24
Paint 6	20.24	18.36	1.88	10.24
Trim 1	30.35	27.54	2.81	10.20
Trim 2	30.35	27.54	2.81	10.20
Trim 3	26.98	24.48	2.5	10.21
Trim 4	26.98	24.48	2.5	10.21
Weld 1	59.02	53.56	5.46	10.19
Weld 2	32.04	29.07	2.97	10.22
Weld 3	30.35	27.54	2.81	10.20
Average	30.71	27.87	2.85	10.21
Average	383 hour	457.3	-74.3*	-16.25*
Average	183.16	284.5	-101.34*	-35.62*
Average	19.9	21.7	-1.8*	-8.29*

*: Reduction (improvement)

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IMPACT OF AIRPORT SERVICE QUALITY, IMAGE, AND PERCEIVED VALUE ON LOYALTY OF PASSENGERS IN SUVARNABHUMI AIRPORT SERVICE OF THAILAND
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IMPACT OF AIRPORT SERVICE QUALITY, IMAGE, AND PERCEIVED VALUE ON LOYALTY OF PASSENGERS IN SUVARNABHUMI AIRPORT SERVICE OF THAILAND

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Keywords: airport service quality, image, perceived value, loyalty, Suvarnabhumi Airport
Abstract: Suvarnabhumi Airport is a gateway to Thailand and Asia. It attracts inbound-, outbound- and transit passengers. The objectives of this study were to develop an airport service quality, image and perceived value framework for the loyalty of passengers and to study the direct, indirect and total effects of the factors that influence the loyalty of passengers who used the service at Suvarnabhumi Airport. This quantitative research method uses the questionnaire as a tool for collecting data from 400 passenger samples. According to the Structural Equation Modelling analysis, airport service quality, image and perceived value have had a positive effect on loyalty that airport service quality mainly has an impact on passenger loyalty. There are four latent dimensions of airport service quality, namely, essential services; comfort, convenience and enjoyment; security, customs and passport control; and special facilities, that can help develop loyalty. Perceived value and image on airport administration and management had a significant direct effect to passenger loyalty. Improving these facotrs in order to attract passenger interest and attention can lead to the development of airport organization performance, and to increase competitiveness as an aviation hub in this region.

1 Introduction

The aviation industry has experienced a massive increase since the 1970s. The Transportation Research Board (TRB) concludes that there has been a 12-fold increase in total passenger traffic over the last 47 years. Growing competition in the airline industry has led to a reduction in air fares and has led to an increase in passenger flow at terminals [1-4].

Many would agree that airports should invest in enhanced facilities and higher levels of service quality in order to attract passengers, thereby generating significantly higher non-aeronautical revenues, which are critical to airport profitability and competition for the organization [5,6]. In addition, service quality is a significant performance indicator for an airport and should be treated with the same level of importance as destination images, profitability, efficiency and loyalty [7-11].

The issue of airport service quality has been extensively examined in the airport literature. For example, the quality of service of 14 major Asia-Pacific international airports using a fuzzy multi-stakeholder decision-making approach [12], passenger expectations of service quality and perceptions of the quality of service at the airport [7,13]. Chen, Li [14] developed and demonstrated a mediation-moderation model of airline service quality influencing passenger repurchase intentions, Jeong and Kim [15] explored the structural relationship between quality, destination image, perceived value, tourist satisfaction and destination loyalty, with emphasis on the mediating effect of tourist satisfaction on desert relations. [15], and the Bezerra and Gomes [9] study examines the loyalty of passengers to the airport by drivers in multi-airport regions.

The aviation industry has undergone changes and challenges over the past year [4,16-18]. Airports of Thailand Public Company Limited (AOT) has accelerated our capacity expansion to meet the growing demand for air traffic at airports within our area of responsibility, while upgrading our organization to a digital operating system

through the use of service, digital technology and innovations based on AOT Digital Platform to enhance overall management efficiency. In other words, airport users can access airport services and data on a real-time basis to plan their activities and effectively manage their time as such, for the last 4 decades, AOT has been proudly operating as a state-owned company that has played an important role in the public and commercial sectors in supporting and driving economic development of the country while delivering value to the airport.

AOT is committed to operating business with a focus on service quality by recognizing the safety and health of employees and employees and being responsible for society, the environment and the community. This will serve as a guideline for sustainable development, thus enhancing the trust and satisfaction of airport users under the slogan 'Safety and service are our priorities.' The year 2018 marks another year of AOT's growth and success, confirmed by awards and awards for its expertise and experience in airport management, which have contributed to the balance of operations in economic, social and environmental terms. AOT was awarded Thailand's Top Corporate Brand Value 2018 for achieving the highest corporate brand value in the transport and logistics industry for the fourth consecutive year and ASEAN's Top Corporate Brand Value 2018 for enhancing the country's socio-economic aspects of sustainable growth [19,20].
AOT operates six international airports in Thailand, namely Suvarnabhumi, Don Mueang, Chiang Mai, Hat Yai, Phuket and Mae Fah Luang-Chiang Rai, providing services to 135 scheduled airlines, comprising 124 mixed passengers – cargo airlines and 11 pure cargo airlines in the fiscal year 2019 [19] as can be seen in Fig. 1 and Fig. 2.

Figure 1 Aircraft movement AOT, 2019 (Airports of Thailand PCL., 2019, p. 148)

The overall performance of AOT air traffic during October 2018-September 2019 improved slightly compared to the same period last year. In the midst of many negative factors, such as the trade war between the US and China, the closure of Pakistan's airspace, Hong Kong protests, Thai baht appreciation, and low-cost airlines reaching a saturation point, global and Thai economies are slowing down. However, the Thai Government has continued to stimulate tourism proactively. This includes extending the visa-on-arrival exemption period for tourists from the end of October 2019 to the end of April 2020 in order to continuously encourage the tourism period for the Chinese New Year and the Songkran Festivals for the year 2020.

Figure 2 Passenger market share in total AOT, 2019[19]

The volume of air traffic from six AOT airports for the year ended 30 September 2019 was 896,097 flights, an increase of 2.41 per cent compared to last year. It consisted of 491,994 international and 404,103 domestic flights. The total number of passengers was 141.87 million, an increase of 1.69 per cent compared to last year. It comprised 84.05 million international passengers and 57.82 million domestic passengers, mainly due to the increase in international flights and passengers. AOT generated net profit of Baht 25,026,37 million in 2019. Baht decreased by 144.39 million or 0.57% compared to the previous year. Total revenues increased by 2.430.86 million Baht, total expenditure increased by 2.073.92 million Baht, and revenue tax expenditure increased by 486.05 million Baht [19] as can be seen in Fig. 3.

Since the middle of the fiscal year 2019, international air traffic has been slowed down due to the decline of the Chinese travel market, Thailand's main market, the uncertain economic war between China and the United States, and the appreciation of the Thai Bath currency, which is increasing travel costs. Although these tourist attractions in Thailand's neighboring countries have become more popular and despite the increase in travelers from other countries, such as India, South Korea and Japan, they have not compensated for the decline of Chinese travelers.

Moreover, the appreciation of Thai currency and the attractions of overseas travelers has encouraged Thais to travel more and more abroad, which has helped to boost the number of international travelers. The number of domestic air traffic has been steadily declining as the domestic airline industry has become saturated, while airlines have avoided fierce competition from low-cost airlines and limited airport facilities, which have caused airlines to turn their attention to international airline marketing. In addition, the decline of travelers to Thailand, in particular Chinese travelers, has resulted in a decline in point-to-point travel among such travelers on domestic routes. The air transport sector has been affected by the economic

situation and the trade war. Overall, airports around the globe are experiencing a decline in air transport, inevitably affecting Thailand's domestic and international transport as well [19] as seen in Figure 4 and Figure 5.

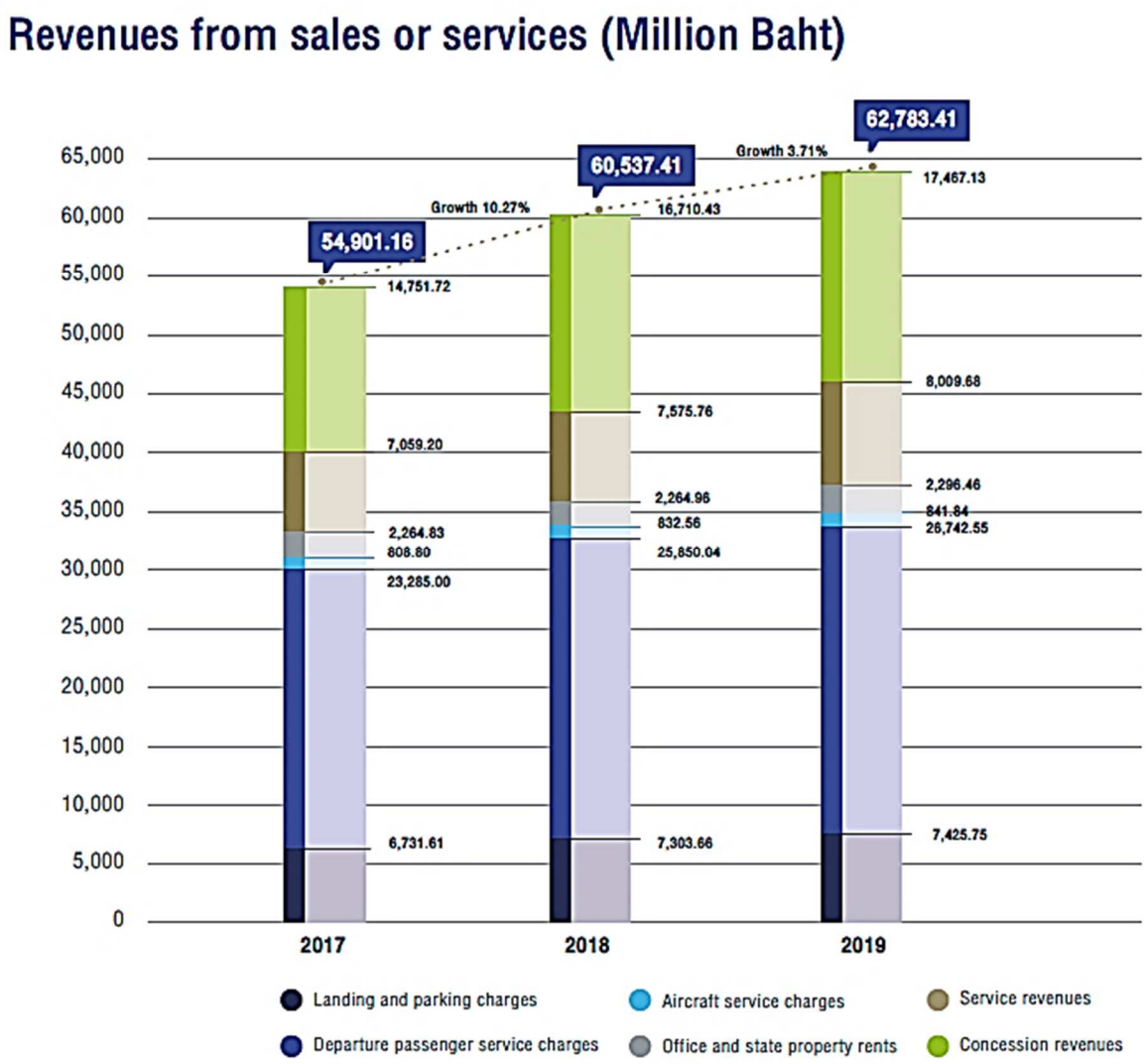

Figure 3 Revenue for sale or service (Million Baht) [19]

: Fiscal Year

	Air Traffic Movements (flights)		
	2018	2019	%
Suvarnabhumi Airport	364,047	378,886	4.08%
Don Mueang International Airport	269,964	273,594	1.34%
Chiang Mai International Airport	75,593	80,534	6.54%
Hat Yai International Airport	29,184	27,045	-7.33%
Phuket International Airport	116,487	115,527	-0.82%
Mae Fah Luang - Chiang Rai International Airport	19,724	20,511	3.99%
Total: 6 airports	874,999	896,097	2.41%

Figure 4 Air traffic 2018-19 [19]

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Surasidh Boonchunone; Mariam Nami; Saowaluck Tus-u-bul; Jaruzgorn Pongthavornvich; Opal Suwunnamek

	Total Passenger Volume (person)		
	2018	2019	%
Suvarnabhumi Airport	62,814,644	64,711,010	3.02%
Don Mueang International Airport	40,563,727	41,008,379	1.10%
Chiang Mai International Airport	10,808,866	11,321,459	4.74%
Hat Yai International Airport	4,265,718	4,028,410	-5.56%
Phuket International Airport	18,260,833	17,848,662	-2.26%
Mae Fah Luang - Chiang Rai International Airport	2,804,700	2,953,096	5.29%
Total: 6 airports	139,518,488	141,871,016	1.69%

Figure 5 Total Passenger AOT 2018-19 [19]

This study focused on the importance of the quality of passenger service at Suvarnabhumi Airport, serving a total of 115 scheduled airlines, comprising 104 mixed passenger-cargo airlines and 11 pure-cargo airlines in the fiscal year 2019, international air traffic has been steadily increasing since last year, partly as a result of domestic flights shifting to international flights, resulting in a significant increase in passenger service [19] as seen in fig. 6. and fig. 7 [19].

Figure 6 Aircraft time at Suvarnabhumi Airport 2008-2019 [19]

Figure 7 Passenger number at Suvarnabhumi Airport 2008-2019

According to the SKYTRAX World Airport Awards rating, an independent rating organization that does not collect fees to assess customer satisfaction for participating airlines and airports, Suvarnabhumi Airport is recognized as the world's top airport. 100 airports ranked 46th in 2019, 48th in 2020 of more than 500 airports, compared to 2018 Suvarnabhumi Airport ranked 36 [21,22].

One basis for the Passenger Loyalty Review is that past research has shown that it is more desirable and much cheaper to retain current passengers than to seek new ones, and that a 5% increase in customer retention can increase profits by 85 per cent [23-25]. Similarly, Assael [26] noted that "success depends not on first purchase but on repurchase, and it is unlikely that any brand can survive over time without some degree of loyalty." Furthermore, loyal passengers are more likely to discuss past service experiences positively than non-loyal passengers, creating a potential for word-of-mouth advertising at no extra cost to the service provider [26]. It is therefore crucial that destination managers understand what makes them loyal to their destination [28].

On the basis of the general acceptance of the notion that loyalty is a driving force when choosing a destination [15,29,30], an increasing number of authors suggest that the image of destination, perceived value and tourist satisfaction could be key factors for the loyalty of destinations in the tourism context. The destination image describes the overall impression of the tourist destination [31] and is linked to their decision-making, choice of destination, subsequent evaluations and future intentions [32,33].

With this variability and uncertainty in terms of requirements, most airline studies claim that "service quality" is the most important and fundamental attribute for an airline to create satisfaction, behavioral intentions and competitive advantage [10,34-37]. Inadequate airport services and facilities influence only operations. However, it can also be seen as a link to a nearby destination that contributes to the development of tourism and logistics transport in the region [9,38,39], significantly increasing the logistics and transport competitiveness of the airport for the organization of the transport sector (Cho & Lee, 2020; D. Shen et al., 2019). There is therefore a growing need to examine to what extent the quality of service is actually associated with the requirements of passengers and why it may also be successful with regard to repurchase intentions [9,11,14,40,41].

However, AOT aims to push Suvarnabhumi Airport to become the world leader in service quality within 6 years and to have the main drivers of infrastructure expansion. Expansion of Suvarnabhumi Airport in Phase Two, based on the advantages of different locations and tourist attractions in Thailand. Suvarnabhumi Airport, on the other hand, is at a disadvantage compared to its larger rivals, Changi Airport. Singapore, which has been ranked the best airport in the world for seven consecutive years by SKYTRAX (2013-2019) in three areas: staff language, airport congestion, and service. These three factors are factors that can be improved and developed. The management of airport services and the recurrence of passengers are key factors in achieving long-term growth and stability. What makes passengers come back to use the service again and to make passengers get the satisfaction of the airport service. In addition, how can the reliability of the airport increase the level of satisfaction and reliability of the airports, that is, increase the quality of airport services?

Passenger loyalty is a key measure of the quality-of-service performance in airports and airline companies and of the mediating role of image and perceived value in the relationship between ASQ and loyalty that has been fully explored in the airport context. They will be useful tools to enhance customer loyalty in travel or tourism [9,30,42-44].

In order to fill these research gaps, a re-examination of the driver or the determinant of passenger loyalty, including a finding of the relationship between the factors, was developed on the basis of literature and used to test several research hypotheses. It also focuses on the comprehensive conceptual framework used, which has important theoretical and practical implications for logistics, transport management and tourism research.

This research selects Suvarnabhumi Airport as a case study with a view to re-examining the issue of airport service quality using image, perceived value that meets airport passengers' loyalty.

1.1 Objective to study

1. To explore an airport service quality, image and perceived value for the loyalty of passengers at Suvarnabhumi Airport in Thailand.
2. To analyze the direct, indirect and total effects of the factors affecting the loyalty of passengers at Suvarnabhumi Airport in Thailand.

2 Literature Review

2.1 Airport service quality

Airports are places where passengers wait for departure to and arrival at destination in a relatively short period of time compared to land and sea transport [45], as a comparison or difference between the expectations of passengers for airport services and their perception of the actual service they receive. Providing services consistent with customer satisfaction that reflect the perception of quality of production and service [11,46,47]. The service is appropriate for the time and costs that passengers have lost, depending on the specific level of expectations of each passenger [48]. Airport service quality refers to the difference between the expectations of the customer and the perception of the actual service received (George et al., 2013). Customers included passengers and airlines offering freight and passenger services in the context of the ACCC

(Australian Competition and Consumer Commission) report [16,49].

The airport service environment is highly complex. Thus, some aspects of passenger-airport interaction may not be sufficiently covered by generic service quality scales (Fodness & Murray, 2007; George, Henthorne, & Panko, 2013; Pantouvakis, 2010). Recent literature has contributed to the alignment of service quality measurement and effective passenger experience with several airport facilities and services [9, 39, 47, 50-53].

In addition, the quality of service of the airport has been formulated for the quality of service dimensions, which include: (1) tangibility, (2) reliability, security and safety (3) responsiveness, (4) assurance (5) effective communication and employee service, (6) additional features and additional features provided, and (7) ticket prices and airline services [14, 34, 46, 48, 54].

From the literature reviews on Passenger Loyalty on the quality of service at the airport. It is what passengers perceive and feel as a result of their actions or activities in the airport area, which were divided into four factors: (1) essential service factor; surface transport to/from airport, airport parking, luggage carts/carts, speed of delivery of luggage, check-in processing time, clear directional signs, flight information screens, internet/Wi-Fi accessibility, toilets, (2) comfort, convenience and enjoyment factor; moving walkways and escalators, sitting facilities throughout the terminal, recharging of batteries, (3) specific equipment factor; bank/ATM facilities, baby changing facilities, telephone, mailing facilities and (4) security, customs and passport control factor; waiting/processing time at security checkpoint, passport control, customs clearance, security and security standards, and customs and passport control standards. The researcher has therefore adopted and summarized the literature review as shown in Table 1.

Table 1 Literature Review of Airport Service Quality

Literature review	Essential Services	Comfort, Convenience and Enjoyment	Special Facilities	Security, Customs and Passport Control
Bezerra and Gomes [50]	✓	✓	✓	✓
Jiang and Zhang [7]	✓	✓	✓	✓
Pandey [39]	✓	✓	✓	✓
Jiang and Zhang [52]	✓	✓	✓	
Pantouvakis and Renzi [55], Pantouvakis [56]	✓	✓	✓	✓
Armenti, Bobbio [57]	✓	✓	✓	✓
Adeniran and Fadare [46]	✓	✓	✓	✓
Gupta [34]	✓	✓	✓	✓
Tsafarakis, Kokotas [58]	✓	✓		✓
Trischler and Lohmann [49]	✓	✓		✓
Prentice and Kadan [10]	✓	✓		✓
Martin-Domingo, Martín [59]	✓	✓	✓	✓
Bezerra and Gomes [60]	✓	✓	✓	✓
Shah, Syed [61]	✓	✓	✓	✓
Thampan, Sinha [1]	✓	✓	✓	✓

2.2 Image

The image of the airport is like a corporate image reflecting the perception of the organization held by the general public. They represent past actions and future behaviors. The image of the organization is very important in the overall assessment of the service and the organization [62-65]. As such, corporate image is very important in the overall assessment of the service and the organization [19,20,65].

In the airport context, there is frightening evidence of the impact of ASQ, image and perceived value on the perception and attitude of loyalty of passengers. These effects may have short-term and long-term implications for travel destinations and logistics and transport management [9,15,50,55,56,66-70].

On the basis of the literature, quality, favorable image and perceived value are positively associated with increased passenger loyalty [9,15,49,62,71-79]. The researcher has therefore summarized the literature review as shown in Table 2.

Table 2 Literature Review of Image

Literature review	Image
Ali, Kim [66]	✓
Pantouvakis and Renzi [55]	✓
Albaity and Melhem [80]	✓
Liu, Li [81]	✓
Tang, Weaver [38]	✓
Zhang, Wu [82]	✓
Bezerra and Gomes [9]	✓
Konuk [83]	✓
Gitto and Mancuso [84]	✓
Jeong and Kim [15]	✓
Nuraida and Danil [45]	✓
Özkan, Süer [78]	✓
Wai Lai [77]	✓
Graciola, De Toni [79]	✓

2.3 *Perceived value*

Customer's perceived value is defined as the ratio of perceived benefit to the compromise of something in exchange for perceived sacrifice [85-90]. Perceived value includes assessments made by customers on the quality and price of products and services after purchase. Perceived value is the perception of value that arises from the comparison of the cost and advantage of the brand to the customers of the product or service. As such, it reflects the customer's comparison between the performance of the service and the price paid for that service [91-94].

Consumer behavior is better understood when analyzed by perceived value, the construction of perceived value has been identified as one of the most important measures, from a consumer research approach, the term perceived value should be understood as synonymous with consumer value [89, 90, 95]. Therefore, the value definition of Zeithaml, which should be considered as part of the trade-off between 'get' and 'give' components, argues that objective quality has no validity and that quality assessments are subjective. This view reinforces the importance of perceived quality, which is the second type of quality. Perceived quality is the general assessment of the customer as to the quality of the product or brand, the conformity with the standards and the performance of its functions [91, 95-97].

The literature on empirical investigation is very often limited to monetary costs, perceived monetary price, perceived risk and time and effort spent [89]. When customers purchase a product or service, they want to gain more value than their cost. In addition, a product or service that creates value enhances satisfaction and leads to repurchase loyalty [91, 97, 98]. Sweeney, Soutar, and Johnson (1999) studied perceived value related to (1) emotional value as a value derived from a feeling or influence on the product, (2) social value is an increase in the social self-concept, a value derived from the capacity of the product. In order to increase the social self-concept, (3) price/value for money is a benefit to the product as a result of the short-term decline in awareness and long-term costs and (4) the value of quality/performance. Zeithaml (1988) therefore argues that objective quality has no validity and that quality assessments are subjective. This view reinforces the importance of perceived quality, which is the second type of quality. Perceived quality is the general assessment of the customer as to the quality of the product or brand, the conformity and performance of the standards and functions [91, 96, 97].

As such, the perceived value is a mediating variable between behavioral intention and loyalty [14, 15, 78, 82, 100-105].

For example, given that the impact of value increases relative to perceived quality, price is a more important determinant of loyalty than quality [89], and perceived value also plays a role as a mediating variable between service quality and behavioral intensity or loyalty [14, 15, 78, 82, 100-105]. The recognition of higher value will therefore have a positive effect on the increased loyalty of passengers to the airport [9, 15, 47, 78, 79].

The researcher has therefore summarized the literature review as shown in Table 3.

Table 3 Literature Review of Perceived Value

Literature review	Perceived Value
Ramseook-Munhurrun, Seebaluck [76]	✓
El-Adly and Eid [106]	✓
Hapsari, Clemes [43]	✓
Bernarto [107]	✓
Safarpour and Sillanpää [108]	✓
Hussein, Hapsari [109]	✓
Konuk [83]	✓
Jeong and Kim [15]	✓
Özkan, Süer [78]	✓
Ahn and Thomas [110]	✓
Bezerra and Gomes [50], Bezerra and Gomes [60]	✓
Graciola, De Toni [79]	✓

2.4 *Loyalty*

Loyalty is the intention of the passenger, to revisit and recommend it to others. It is a sign of intention to return again and to be willing to recommend it to others [111,112]. Loyalty refers to a positive attitude towards a badge that leads to ongoing trading as a result of the consumer's learning that a badge can meet their needs [113,114].

Customer loyalty has been a key issue in marketing literature as a strategic objective for organizations in very competitive environments. Comprehension of behavior and loyalty factors is imperative for customer retention, positive word-of-mouth gain, repurchase and increased revenue [9,62,115-119]. Despite the debate on Passenger Loyalty in the airport industry, there is a lack of empirical evidence of the nature and loyalty of passenger loyalty

drivers to airports. Although service experience and satisfaction levels play a key role, airport passenger behavior may depend on a number of other peculiarities, including passenger and market characteristics [9,67,120-123].

Bearing these considerations in mind, in this study, the quality of airport services, image, perceived value was considered to be direct, indirect, and the overall effect of factors that influence passenger loyalty. The search for a more comprehensive approach [7,9,50,92,124,125].

Customer attitudes and expectations reflect the attributes and characteristics of the airport service experience expected/anticipated by the customer, such as word of mouth and revisit [119,126,127], as well as their impact on the customer attitude towards the airport and the passenger, in this paper, the image and perceived value mediate their post-purchase behavior. As such, the direct, indirect and total impact of the factors that influence the loyalty of passengers to the airport.

Regardless of the sources of attitude/expectations, it is assumed that passengers will evaluate their experience on the basis of these attributes/characteristics, and then form their opinion on the entire experience [119]. Based on previous research, including the rationale for the conceptual model, the hypothesized relationship with respect to the attitude of passengers includes the positive direct, indirect and total effects of ASQ, perceived value on the loyalty of passengers at the airport.

The researcher has therefore summarized the literature review as shown in Table 4.

Table 4 Literature Review of Loyalty

Literature review	Loyalty
Ramseook-Munhurrun, Seebaluck [76]	✓
Su, Swanson [128]	✓
Abid, Zahra [129]	✓
Albaity and Melhem [80]	✓
Prayag, Hosany [130]	✓
Espinosa, Ortinau [131]	✓
Liu, Li [81]	✓
Moon, Yoon [36]	✓
Konuk [83]	✓
Bezerra and Gomes [9]	✓
Martin-Domingo, Martín [59]	✓
Graciola, De Toni [79]	✓
Pandey, Tripathi [132]	✓
Shen and Yahya [54]	✓

Following the literature review, the model is shown in Fig. 8. Was developing, and the hypothesis is as follows:

Hypothesis 1: Airport Service Quality has an indirect impact on loyalty.

Hypothesis 2: Airport Service Quality directly affects the image.

Hypothesis 3: Airport Service Quality directly affects the perceived value.

Hypothesis 4: Image directly affects the perceived value.

Hypothesis 5: Image directly and directly influences loyalty.

Hypothesis 6: The perceived value directly affects loyalty.

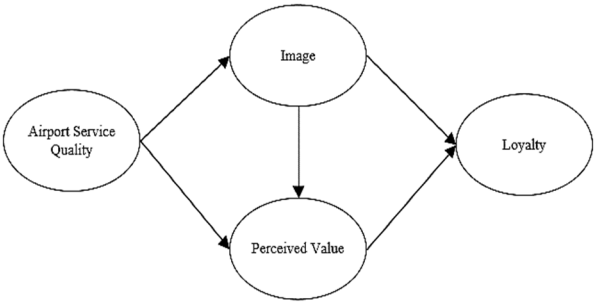

Figure 8 Conceptual framework

3 Methodology

As an empirical research, the researcher used quantitative research methods [133]. The questionnaire tool was used to collect passengers at Suvarnabhumi Airport in Thailand. The choice of convenience was used by the respondent, by distributing questionnaires online, by scanning the QR code of 250 copies for Thai passengers and 100 copies, and online questionnaires by scanning the QR code of 50 copies, including 150 copies of foreign passengers in front of Suvarnabhumi Airport and the customs checkpoint for the return of the tourist tax (VAT Refund). The survey was conducted from January 2020 to February 2020.

3.1 Design of the questionnaire

The data collection instrument consisted of questionnaires, consisting of (1) demographic data and (2) quantitative attitude questionnaires, which measure 4 latent and manifest variables-airport service quality, image, perceived value and loyalty. We use the Likert scale of the 6-point scale was scored as 1= strongly disagree, 2= disagree, 3= somewhat disagree, 4= somewhat agree, 5= agree, and 6= strongly agree [134-136] as shown in Table 5.

Context Validity is checked by 3 experts for consistency in the examination. The questionnaire was then used to find the Index of Item Objective Congruence (IOC) before the IOC questions of 0.5 and up were selected [139]. Subsequently, the revision of the questionnaire and the collection of basic data from the 30 samples were carried out for the analysis of the measurement using the Cronbach alpha coefficient (ш-coefficient). The questionnaire was used for empirical variables with a reliability of more than 0.70, which is considered to have a high level of reliability [140]. This research was carried out with the Cronbach's Alpha Measure of Internal Consistency and the result was 0.913.

Table 5 Questions on Measurement and Development

Latent and Manifest Variables	Development
Airport Service Quality (ASQ) 1) Essential Services Comfort 2) Convenience and Enjoyment 3) Special Facilities 4) Security, Customs and Passport Control	Jiang and Zhang [7], Bezerra and Gomes [9], Pandey [39], Adeniran and Fadare [46], George, Henthorne [47], Bezerra and Gomes [50], Bezerra and Gomes [51], Armenti, Bobbio [57], Widarsyah [137]
Image (Image)	Bezerra and Gomes [9], Ashraf, Ilyas [73], Özkan, Süer [78]
Perceived Value (PV)	Bezerra and Gomes [9], [15], Bernarto [107]
Loyalty	Bezerra and Gomes [9], Moon, Yoon [36], Saleem, Zahra [48], Bernarto [107], Suki [138]

3.2 Data Collection

The population in this study was passengers at Suvarnabhumi Airport in Thailand. Information from passengers traveling in and out of Suvarnabhumi Airport, 52,694,699 people. Data collection was carried out using a questionnaire; it was carried out in order to find answers about concepts. The questionnaires were collected and the data analyzed were used to determine the size of the sample. By specifying the ratio of 20 samples to 1 variable, this equaled 20 variables x 20 = 400 cases [141], and used Simple Random Sampling. The analysis of the Structural Equation Model (SEM) required a larger sample size than the other methods to provide an accurate estimate and to be suitable for the population. The data was distributed as standard curves [140].

4 Data analysis

4.1 Structural Equation Model Analysis Results

Table 5 The analysis was carried out using a statistical program, the IBM SPSS Amos 22 software (Statistics Package for the Social Science Analysis of Moment Structures) that used the Structural Equation Modelling (SEM), which allows researchers to benefit greatly from the SEM technique used to examine the relationship between different variables and to analyse direct-indirect influences at the same time. Including the analysis of the relationship between latent variables and indicators or empirical variables to check the harmony and hypothesis testing of the relationship between latent variables and manifest variables. The results were analysed using the Structural Equation Model by determining the variable and latent variables analysed by the reflective gauges. The test of consistency between the Goodness of Fit Measures Model was carried out and it was found to be in harmony with the fit of the model, with the following result: Chi-square (χ^2) = 155.022, df = 126, CMIN/DF (χ^2/df) = 1.230, GFI = .971, CFI = .988, AGFI = .939, RMSEA = .049, and Hoelter = 395 (Fig.3.). It can be summarized that the form of the structural equation of the variables affecting passenger loyalty in the Suvarnabhumi Airport Service of Thailand was consistent with the empirical data [141-144] Accordingly, the researcher summarized the statistics Goodness of fit as shown in Table 6.

Table 6 Statistics Goodness of fit [140-142]

Relevant Statistics	Criteria	Test Value
Relative Chi-square	$\chi 2/df < 2.00$	1.230
Goodness of Fit Index	GFI >.95	.962
Adjusted Goodness of Fit Index	AGFI >.95	.963
Comparative Fit Index	CFI >.95	.996
Norm Fit Index	NFI>.95	.994
Tucker-Lewis Index	TLII >.95	.936
Root Mean Square Error of Approximation	RMSEA <.05	.024
Hoelter Default Model (p<.05)	Hoelter>200	395

From table 7, Airport Service Quality had a standardized regression weights between .754 to .897, and squared multiple correlation (R^2) was between .596 to .804. Image had a standardized regression weights between 748 to .891, and the squared multiple correlation (R^2) was between .559 to .796. Perceived value had a standardized regression weights between .880 to .922, and the squared multiple correlation (R^2) was between .765 to .832. And loyalty had a standardized regression weights between .659 to .795, and the squared multiple correlation (R^2) was between .420 to .670. All of the factors were statistically significant. Also, the standardized regression weight was

of high value. Therefore, the observable variables or empiric variables had appropriate harmony as a factor for the measurement of the latent variable.

The following equations were formed from the results of the Structural Equation Modeling analysis:

$$Image = .872\ Airport\ Service\ Quality, R^2 = .760 \quad (1)$$

$$Perceived\ Value = .310\ Airport\ Service\ Quality + .533\ Image, R^2 = .668 \quad (2)$$

$$Loyalty = .704\ Image + .257\ Perceived\ Value, R^2 = .852 \quad (3)$$

4.2 Results of testing of the hypotheses

Hypothesis testing shall provide the same analysis as the Structural Equation Modeling by considering the C.R. (t-value) and p-value used for the test of the hypothesis, as well as the analysis, to determine the influence of each pair of variables, both direct and indirect, as well as the influences. The analysis was carried out using the IBM SPSS AMOS software. The results of the test were the standard regression coefficient (coef.) of all C.R. research hypotheses correlations. Values higher than 1.96 for all hypotheses of statistical significance. It can therefore be concluded that the results of the analysis support all assumptions and that the results of the analyzes of the researcher's factors are shown in Table 7, 8, 9, and the Final Model Fig. 8.

Hypothesis 1: Airport Service Quality has an indirect impact on loyalty. As far as the hypothesis testing is concerned, coef. =.813, which supports a statistically significant hypothesis at p<0.001.

Hypothesis 2: Airport Service Quality directly affects the image. As far as the hypothesis testing is concerned, coef. =.872, which supports a statistically significant hypothesis at p<0.001.

Hypothesis 3: Airport Service Quality directly affects the perceived value. As far as the hypothesis testing is concerned, coef. =.310, which supports a statistically significant hypothesis at p <0.001.

Hypothesis 4: Image directly affects the perceived value. As far as the hypothesis testing is concerned, coef. =.553, which supports a statistically significant hypothesis at p<0.001.

Hypothesis 5: Image directly influences loyalty. As far as the hypothesis testing is concerned, coef. =.704, which supports a statistically significant hypothesis at p<0.001.

Hypothesis 6: The perceived value directly affects loyalty. As far as the hypothesis testing is concerned, coef. =.257, which supports a statistically significant hypothesis at p<0.001

5 Discussion and Implementation

5.1 Management implications

Airport service quality faces unwavering competition, risk and resilience in radically redefined environments; information practices during the COVID-19 pandemic; uncertainty about the further impact of the current situation; and challenges posed continue to intensify [7,9-11,15,145-147], and therefore it is important to understand what drives the behaviour of passengers. From a practical point of view, our findings have significant managerial implications for airport destinations. Based on the results of the current study, we are offering the following plan to maximize service quality, as this strategy is expected to increase image, perceived value, and passenger loyalty.

In addition, we suggest that airport managers consider these four latent dimensions of airport service quality to ensure that the needs and wishes of passengers are met. Improving and enhancing the quality of service to attract passenger interest and attention (1) essential services, (2) comfort, convenience and enjoyment, (3) security, customs and passport control, and (4) special facilities to attract passenger interest and attention as essential logistics services; baggage carts/carts, surface transport to/from airport, airport parking, and speed of baggage. These are the motivation behind the participation and satisfaction of passengers in airport service providers. In addition, essential passenger services in successful services have a positive impact on the image of the airport, perceived value and have a positive impact on passengers' loyalty.

Efforts should also be made to provide passengers with quality services. Intuitively, comfort, convenience and enjoyment, security, customs and passport control, and special facilities, add passenger experience, satisfaction, airport image, perceived value and increase the likelihood of revisits and destination recommendations to family, friends and acquaintances.

In order to improve the quality of the interaction service, the service provider should be trained and trained to create the right attitude; a warm Thai smile and friendly attitude during the service enhance the image of the airport and the perceived value of passengers. With regard to the quality of environmental services, airport managers should pay more attention to: first, comfort, convenience and enjoyment, second, security, customs and passport control and, finally, special facilities. Sometimes, detecting, fixing delays or failing to complete facilities compromises passengers. Therefore, these should be considered a priority when they serviced [7,9,15,103].

The present study confirms that the quality of service is positively linked to the image of airport perceived value, loyalty, which highlights the important contribution made by the quality of service of the airport to the development of individual satisfaction and loyalty. The management objective should therefore be to improve the quality of the airport's service to its destination. Airport managers could improve service quality by using innovation and information technology and communication, such as the

social media platform, Facebook, Instagram, line, twister, tube, and blog, should be considered Internet-based applications containing consumer-generated content supported by social media that generate and share passenger experiences, planning, ideas and opinions.

5.2 Research implications

The present study advances knowledge of air travel for passengers by investigating links between airport service quality, airport image, perceived value, and passenger loyalty. Findings indicate that airport service has a direct impact on airport image quality and perceived value. Moreover, the image of airport direct effect perceived value, the image of airport direct effect loyalty, perceived value of direct effect loyalty, and the mediating role of airport image and perceived value in the relationship between airport service quality and loyalty are both positive and significant. From a theoretical point of view, this study has several implications for research in the field of tourism, logistics and transport management.

First, the present study found three important drivers of passenger loyalty, with significant impacts on all segments of passengers: airport service quality (ASQ), airport image, and perceived value. The quality of service, measured using a multidimensional scale specifically designed for airports [7,15,47,49,55,151] influences the loyalty of passengers to the airport through their image and perceived value [9,14,60,103,152,153]. This means that the quality of airport services can contribute to maintaining the long-term preference of the airport [9,14,30,154].

Second, the current study responds to the recent call for integrated models for marketing, tourism, logistics and transport researchers [9,15,60,76,153,155]. More specifically, in order to develop a stable air service quality model, we include passenger loyalty in the proposed model.

Third, the impact of airport service quality on passenger loyalty is mediated by their image of the airport and perceived value. This finding may have implications for the destination and transportation of passengers [9,10,13,15,38,70,156]. These three drivers of passenger loyalty, recognized as being very important for business organizations wishing to compete globally, have been valued in the literature on airport and transport management. These results may suggest that airports are not only viewed as a mode of transport infrastructure, but that they should be viewed as partners in the tourist service chain through tourism management, logistics and transport.

Finally, passenger loyalty has a significant impact on the quality of airport services. The image of the airport for passengers and perceived value (Tables 2 and 3) has a significant impact on the ASQ for passengers. Although there is no direct impact on the loyalty of passengers on the quality of airport services, but there is also a significant indirect impact on the loyalty of passengers to the airport, there is a possibility that passengers experienced by providing good quality services through a modern airport can prepare for the future and trust the image of the administration. As such, passengers are impressed and feel that they are getting value for both the quality and the money of the goods and services they pay for.

6 Conclusions

As we have seen, the main purpose of this study was to investigate the structural relationship between airport service quality, airport image, perceived value and passenger loyalty, with emphasis on the mediating effect of airport image, perceived value on the relationship between airport service quality and passenger loyalty in Thailand's Suvarnabhumi airport service.

The findings showed significant impacts of airport service image quality and perceived value on passenger loyalty; and demonstrated airport image, perceived value fully mediates the relationship between airport service quality and passenger loyalty.

Based on the results, the contribution of this study was to incorporate service quality and value into airport image, perceived value and passenger loyalty model; demonstrated empirical evidence that airport image fully mediates the relationship between airport service quality and loyalty; and airport image and perceived value fully mediates the relationship between airport service quality and loyalty in the travel, logistics, and transportation businesses. As such, the quality of airport services has a major impact on the development of airport organization, contributing to the continuous growth of operating performance, as well as increasing competitiveness, and making commercial aviation a sustainable hub.

In today's competitive environment, business organizations need to find innovative information and communication strategies to distinguish them from their competitors.

Although this approach is not new to competitive business organizations, it has only recently begun to be followed by organizations that do not typically have customer-specific business activities, such as airports. Whereas the overall attractiveness of the airport depends on a number of factors (e.g., hub, destinations, airport layout, market power, integration with the logistics system, economic strength, air fare, distance, flying time, location, routes, scheduling, etc.), airport managers are increasingly concerned with a customer-oriented approach to achieving competitive advantage and sustainability. In addition, airports are used as transport infrastructures and regional development tools not only for the logistics and transport sector, but also for the tourism sector. In this context, this study brings together a number of theoretical and practical contributions to airport management, tourism management, logistics and transport.

Although this study sheds light on the benefits of using an integrated approach to improving airport service quality, airport image, perceived value and passenger loyalty, it has several limitations.

In this context, it is essential to know the characteristics and behavior patterns of their passengers. As such, they will be able to design organizations that focus on business activities and that focus on individual passengers, such as airports.

First, we have not investigated other external factors, including the positive impact of the factors. Additional studies are needed to explore the effects of more of these variables in order to broaden the understanding of the forces driving travel and the loyalty of passengers (e.g. airport management, operating drivers, characteristics of airports, etc.) [157].

Second, the image of the airport and perceived value were examined as potential mediators of the relationship between the image of the destination and the loyalty of the destination. However, the effects of other potential mediators (e.g. airport re-use, corporate reputation, location attachment, trust, passenger complaints, satisfaction, switching behavior, etc.) should be investigated in order to provide a more comprehensive conceptual framework.

Third, the findings of our study may not apply to other airport service destinations because the characteristics of the Suvarnabhumi airport service in Thailand may differ. In order to make our findings more general, similar studies are required in other tourist destinations.

Fouth, in this study, data were collected during the early outbreak of COVID-19, affecting the feelings and attitudes of survey respondents, which may influence the results of a bias analysis. The results of this study should be confirmed once the outbreak of COVID-19 has been fully controlled and causes a return to normal.

Finally, passenger loyalty has a significant impact on the quality of airport services. The image of the airport for passengers and perceived value (Tables 2 and 3) has a significant impact on the ASQ for passengers. Although there is no direct impact on the loyalty of passengers on the quality of airport services, but there is also a significant indirect impact on the loyalty of passengers to the airport, there is a possibility that passengers experienced by providing good quality services through a modern airport can prepare for the future and trust the image of the administration. As such, passengers are impressed and feel that they are getting value for both the quality and the money of the goods and services they pay for. The result, therefore, is a word of mouth and willing to revisit this airport the next time it travels to another country.

Acknowledgement
We would like to thank the university, advisors, experts, and Suvarnabhumi Airport Passenger Customs Office for facilitating the distribution of questionnaires. Further, this research could not have been successful without the support and related information provided by the information contributors who all respondents for their cooperation and taking the time to answer the questionnaire in Suvarnabhumi Airport of Thailand.

Table 7 Analysis on the relationship of the variables

Relationship of Variables			Standardized Regression Weights	S.E.	Squared Multiple Correlations	C.R.	P
Image	<---	Airport Service Quality	.872	.060	.760	20.001	***
Perceived Value	<---	Airport Service Quality	.310	.107	.668	3.964	***
Perceived Value	<---	Image	.533	.079		6.620	***
Loyalty	<---	Image	.704	.059	.852	10.584	***
Loyalty	<---	Perceived Value	.257	.058		3.994	***
Essential Services Comfort	<---	Airport Service Quality	.897	-[a]	.804	-[a]	-[a]
Convenience and Enjoyment	<---	Airport Service Quality	.837	.044	.700	22.679	***
Special Facilities	<---	Airport Service Quality	.754	.050	.569	18.644	***
Security, Customs and Passport Control	<---	Airport Service Quality	.794	.051	.630	20.746	***
Image1	<---	Image	.891		.795		***
Image2	<---	Image	.859	.042	.739	24.525	***
Image3	<---	Image	.775	.049	.600	20.050	***
Image4	<---	Image	.824	.042	.796	22.984	***

IMPACT OF AIRPORT SERVICE QUALITY, IMAGE, AND PERCEIVED VALUE ON LOYALTY OF PASSENGERS IN SUVARNABHUMI AIRPORT SERVICE OF THAILAND

Surasidh Boonchunone; Mariam Nami; Saowaluck Tus-u-bul; Jaruzgorn Pongthavornvich; Opal Suwunnamek

Relationship of Variables			Standardized Regression Weights	S.E.	Squared Multiple Correlations	C.R.	P
Image	<---	Airport Service Quality	.872	.060	.760	20.001	***
Perceived Value	<---	Airport Service Quality	.310	.107	.668	3.964	***
Perceived Value	<---	Image	.533	.079		6.620	***
Loyalty	<---	Image	.704	.059	.852	10.584	***
Loyalty	<---	Perceived Value	.257	.058		3.994	***
Image5	<---	Image	.748	.056	.559	18.533	***
Perceived Value1	<---	Perceived Value	.904	-[a]	.790	-[a]	-[a]
Perceived Value2	<---	Perceived Value	.912	.041	.832	26.610	***
Perceived Value3	<---	Perceived Value	.897	.040	.804	25.593	***
Perceived Value4	<---	Perceived Value	.880	.044	.774	23.075	***
Perceived Value5	<---	Perceived Value	.922	.045	.765	23.182	***
Word of Mouth1	<---	Loyalty	.797	-[a]	.670	-[a]	-[a]
Word of Mouth2	<---	Loyalty	.672	.051	.478	16.824	***
Word of Mouth3	<---	Loyalty	.795	.060	.631	19.461	***
Revisit1	<---	Loyalty	.719	.065	.518	15.303	***
Revisit2	<---	Loyalty	.659	.070	.420	12.972	***
Revisit3	<---	Loyalty	.743	.063	.551	15.911	***

Note: -[a]; Fixed parameter does not display the Standard Error (S.E.), Critical Ratio (C.R.) and the Probability Level (P).

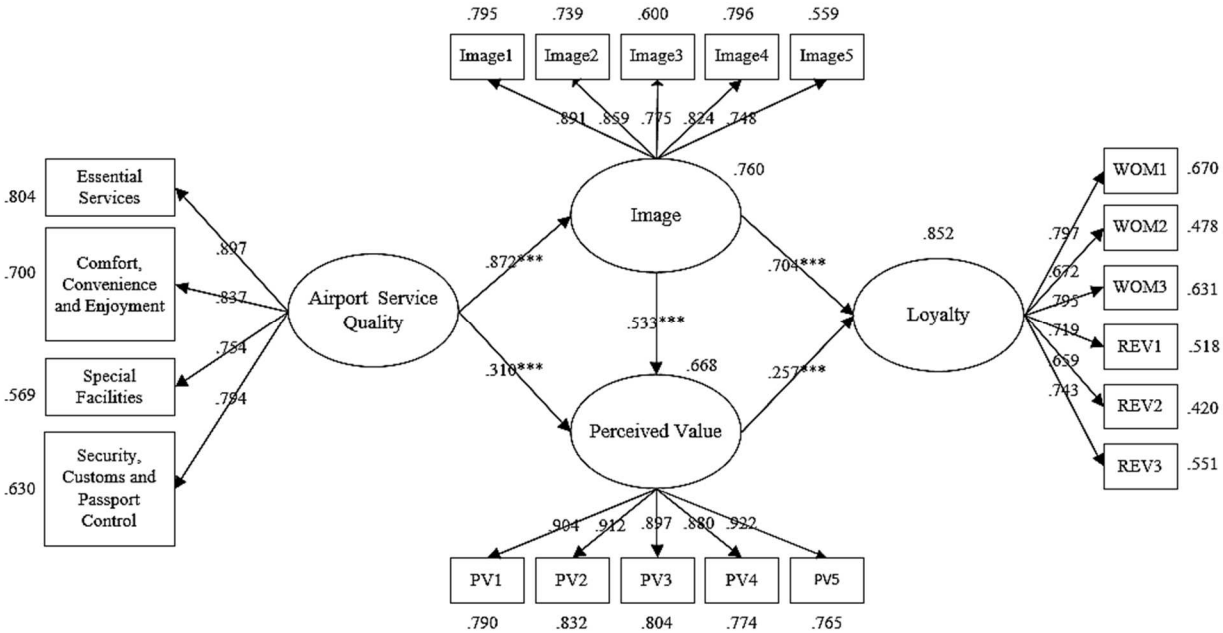

Figure 9 Final model

Table 8 Hypothesis test results

Hypothesis	coef.	*t*-test	Results
H1: Image <--- Airport Service Quality	.872***	20.001	Supported
H2: Perceived Value <--- Airport Service Quality	.310***	3.964	Supported
H3: Perceived Value <--- Image	.533***	6.620	Supported
H4: Loyalty <--- Image	.704***	10.584	Supported
H5: Loyalty <--- Perceived Value	.257***	3.994	Supported

Note: Coefficient: coef., *** p < .001, Coefficient refer to the Beta (β)

Table 9 Standardized direct, indirect, and total effects of the factors test results

Effects	Total				direct				Indirect			
Variables	ASQ	Image	PV	LOY	APSQ	Image	PV	LOY	APSQ	Image	PV	LOY
Image	.872	.000	.000	.000	.872	.000	.000	.000	.000	.000	.000	.000
Perceived value	.775	.533	.000	.000	.310	.533	.000	.000	.464	.000	.000	.000
Loyalty	.813	.840	.257	.000	.000	.704	.257	.000	.813	.137	.000	.000

Note: Airport Service Quality (ASQ), Image (Image), Perceived value (PV), Loyalty (LOY)

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RETURN PACKAGING IN THE SHIPMENT PROCESS OF READY PRODUCTS ON THE EXAMPLE OF VOLKSWAGEN MOTOR POLSKA SP. Z O.O.

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Keywords: supply chain, returnable packaging, shipment preparation
Abstract: Nowadays, the effectiveness of the enterprise depends on all departments of enterprises, including logistics. One of the strategic areas of logistics, although often overlooked, is the turnover of returnable packaging. Turnover of packages is an additional process in the enterprise that creates additional costs. With the optimal management of this process throughout the entire supply chain, enterprises can minimize the costs associated with it. This study presents the process of managing returnable packaging. The aim of the work is to identify and analyze the possibility of using returnable packaging in the process of preparing shipment and transport of finished products in the automotive industry. The article uses a case study of one of the companies operating in the automotive industry - Volkswagen Motor Polska sp. z o.o. The article presents three possible solutions for the transport of engines manufactured by the described company. One of the solutions is currently used by enterprises. The other two are a proposal to apply. When analyzing the costs of these solutions, the best one was presented, the costs of which will be the most profitable in the long run.

1 Introduction

In the modern economy, the activity of almost every enterprise is based on cooperation with other co-operators in an integrated structure implementing tasks consistent with the common goals of its participants. An example of such a structure is the supply chain defined by J. Witkowski [1] as "mining, production, trade and service companies cooperating in various functional areas and their clients, between which streams of products, information and financial resources flow". The main goal of supply chain operations is to deliver products to the final customer while maintaining the highest quality and minimizing flow costs [2]. The success of supply chain management depends not only on the integration of main processes such as transport, storage or coordinating information flows, but also on many activities indirectly related to the main flows, among which packaging management can be distinguished. The use of appropriate packaging and effective management means that not only ensure that the product reaches the customer in an unchanged condition, but can also ensure long-term savings and the implementation of the principles of sustainable development. This means that companies must adapt to new customer requirements and constantly growing competition [3].

The aim of this study is to identification and analysis the possibility of using returnable packaging in the process of preparing shipment and transport of finished products in the automotive industry. The article uses a case study of one of the companies operating in the automotive industry. For the purposes of the research, literature studies, documentation analysis and a single case analysis were carried out. This research seems to be very important from the point of view of the theory of logistics management and the practical aspects of the functioning of companies. This topic is located in the manufacturing, distribution, reverse logistics, but also sustainable development and environmental aspects. Currently, few companies use returnable packaging in supply chains, but this is undoubtedly the direction of further development and challenges faced by companies.

2 Role and types of returnable packaging in supply chain management

Packaging plays an important role in the supply chain during almost all phases of its activity, i.e. material delivery, storage, preparation for production and distribution [4]. Among the functions of packaging can be distinguished, among others [5,6]:

- securing the content - preventing the product from reaching the customer incomplete or defective by e.g. additional securing the goods on the pallet with foil, placing a set consisting of several products in one package,

- mechanical protection of products - reduction of the risk of potential damage caused by external factors (e.g. shocks, pressure, temperature, etc.),
- providing information - placing information on the packaging regarding the use of the product, storage methods or handling waste generated after the use of the product or packaging,
- marketing function - using the packaging as an element to encourage customers to buy the product by designing the right combination of colours, shapes, graphics and size.

The role of packaging also depends on the characteristics of the product. Depending on the subject of the flow, additional requirements must be met, for example, food and drugs must be stored in sterile containers to prevent biological and chemical transformations, and metals need additional protection against corrosion.

Packaging can be divided according to various criteria. Due to the function performed, one can distinguish unit packaging (direct packaging of a single product), transport packaging (used for storage and transport operations before delivery to the final customer) and collective packaging (intermediate between unit and transport packaging, often used in retail outlets). Another classification can be proposed taking into account the material that was used to make the packaging. In this case, the most popular are paper and cardboard (e.g. paper bags, cartons), wooden or metal (boxes, pallets) and plastic (foil, containers) etc. From the point of view of environmental protection, they can be divided into undergoing or not subject to a natural decomposition process. In enterprises, packaging can be their own, belonging to the supplier or leased [7]. A very important issue in the marketing of packaging in the supply chain is whether it is disposable or reusable. Those used only in one process do not require additional activities related to the flow of returnable packaging, but can be disadvantageous from the point of view of costs and environmental protection. Multiple-use packaging has many advantages, but its use requires the coordination of chain-back processes.

The use of returnable packaging is the key to achieving the principles of sustainable development and long-term savings. Multiple use of pallets, boxes, Big Bags and other containers is an integral part of the activities of many enterprises. This is a positive phenomenon, however, it concerns the main transport packaging, and does not include auxiliary ones, such as stretch foil [8]. The consumption of materials (mainly plastics and paper) and the increasing amount of packaging waste are becoming more and more important environmental problems. The scale of the problem is evidenced by the fact that, according to Eurostat data, in 2018 around 77.7 million tonnes of packaging waste was generated in the European Union, which is approximately 174 kg per capita [9]. Such a situation requires the use of modern solutions that will effectively and positively replace the methods of securing products used by enterprises. An example of a real alternative to single-use packaging used to secure pallets are covers of companies such as Techcycle Technology Inc. and Pallet Wrapz Inc. which can successfully replace stretch foil [10,11].

Additionally, the environmental criterion should take into account the economic aspect of using returnable packaging. Giving up disposable packaging can bring long-term savings, but also turn out to be unprofitable, so the decision should be based on an analysis that takes into account all the advantages and disadvantages. The costs related to the use of returnable packaging include: the need to invest a large amount of money at one time to purchase the amount of reusable packaging necessary for the system to function, costs of packaging transport and those related to the management of packaging flow within the company and quality control. On the other hand, this solution brings benefits resulting from the lack of the need to cyclically buy packaging and get rid of the used ones, as well as greater efficiency of logistics processes [12]. In addition to the above-mentioned factors, the specific nature of the supply chain has a significant impact on the profitability of introducing returnable packaging. The first issue that should be distinguished is the effectiveness of packaging flow management, and more specifically ensuring that they always go to the right place at the right time. Any downtime of containers at customers or other chain links means that the system does not use its full potential, which may lead to the feeling that there is too little packaging and force you to buy them. This is a significant issue as each excess container in the system increases payback times. In addition, controlling the shipment of products is crucial. The returnable packaging system is more effective for more frequent shipments with a shorter cycle time and less effective for longer distances and in situations of large fluctuations in demand [13]. It depends on the frequency of shipments when the investment in reusable packaging will pay for itself, and on their stability and regularity, determining the demand for containers that will be optimal for the functioning of the system.

The returnable packaging system in the supply chain can be organized in various ways, depending on the needs and preferences of its links. One of the classifications distinguished in the literature identifies the following systems [14]:

- system of removable pool,
- system with return logistics,
- system without reverse logistics.

In the **system of removable pool**, responsibility is distributed - each participant has a specific number of containers that he manages and maintains in the best condition and quality. The participants of the system may only be the sender and the recipient, or additionally a carrier who has its own pool of packages and passes them on to other participants when collecting full containers. In the **system with return logistics**, the packages are owned

by the central link in the supply chain, which is responsible for the return of empty containers. In this case, the flow of packages may take place on the sender - recipient line or with an intermediate link - the container warehouse. In the **system without return logistics**, there is also one company that owns but only rents the containers. During the temporary possession of the packages by the sender, he is responsible for their technical condition, storage and all processes related to return logistics.

The use of new solutions and tools to optimize logistics processes is valuable, but the costs of these implementations should always be reimbursed in relation to the total costs incurred by the company [15].

3 Process of preparing products ready for shipping and transport in Volkswagen Motor Polska sp. z o.o.

Volkswagen Motor Polska Sp. z o.o. belongs to the Volkswagen AG concern, which is one of the leaders in the automotive industry. The headquarters of the company was established in 1999 in a subzone of the Legnica Special Economic Zone in Polkowice in Lower Silesia. The company specializes in the production of diesel engines in Common Rail and MDB technologies. The factory in Polkowice is a very important link in the concern's supply chain providing key components for cars for the needs of the assembly plant in Poland and around the world, including in the Czech Republic, Germany and Spain. Ensuring the highest quality requires not only the improvement of production processes, but also logistics, which include organizing and controlling the shipment of finished products.

The process of preparing engines for shipment begins at the time of final production acceptance, where the products are packed and prepared for storage and transport. The next processes related to the execution of the customer's order take place after the engines are transported to the shipping warehouse. A simplified scheme for controlling the shipment of finished products is shown in Figure 1.

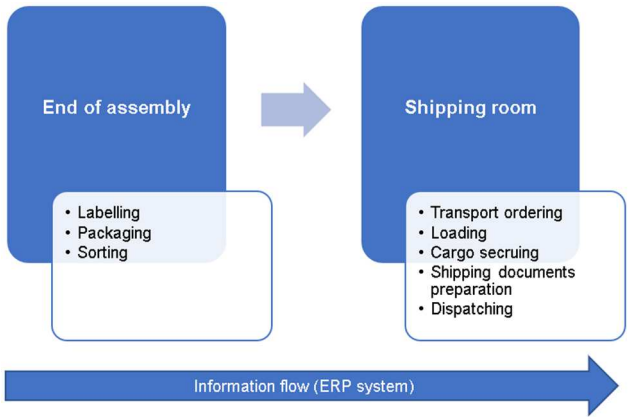

Figure 1 Controlling the shipment of finished products

After exiting the final assembly line, the motors are inspected for compliance and then labeled. If the product meets the requirements, it is marked with a label with the number of the material card (HU – handling unit). The products prepared in this way are packed on MTG – steel pallets for 6 motors. In addition, the products are secured with adapters that prevent shifting within the pallet. A set consisting of a pallet, 6 motors and 6 adapters is marked with a label containing, among others place and date of production, purpose of shipment, gross and net weight of the set, identification number and barcodes enabling communication with the ERP system. After the finished engines are booked into the warehouse and the audit is carried out, they are protected with corrosion protection foil and stored.

The next stage of preparing products ready for shipment and transport begins after the engines are transported to the shipment warehouse and booked in there by the forklift operator using a barcode scanner. The next steps depend on the engine shipment control worker ordering the shipment in the system ERP and the person ordering the transport at the forwarder. Upon arrival of the transport, it is checked for compliance with certain conditions. The truck must first of all be equipped with anti-slip mats and load securing belts that minimize the risk of damage to the engines during transport. If the arrival is consistent with the order, the order is printed and then the products are taken from the warehouse, which must be confirmed in the ERP system. After the products are picked up, they are loaded on the truck and secured by the driver. In each transport, from 12 to 15 pallets are loaded, which means from 72 to 90 engines. The last step before the truck is cleared is to prepare the shipment documents and hand them over to the driver. For the shipment of engines, the necessary documents are the transportation workflow, the CMR international consignment note and the ERP shipment document. Handover of documents and truck clearance are activities that end the shipment of finished products in the company. The result of the process is then assessed by the customer according to the group's "supplier quality assessment" procedure.

4 Proposal of new solutions in the process of preparation and transport of finished products in Volkswagen Motor Polska sp. z o.o. - results and disussion

The potential area of optimization of the preparation and transport of finished products at Volkswagen Motor Polska Sp. z o.o. there is a change in the packaging used. Currently, two types of returnable packaging are used for shipping - MTG pallets and adapters that prevent the cargo from shifting. Additionally, in the period from October to March, due to the high risk of corrosion of engines, additional disposable packaging - VCI bags are used. These packages are an important flow element as they protect products against loss of quality and corrosion

damage. In the VCI bag, in which the engine is packed, volatile corrosion inhibitors evaporate and form a protective layer on the metal. An additional advantage of this solution is that after unpacking, the products can be immediately used for subsequent processes without the need to get rid of the agent from their surface [16]. These packages are successfully used in practice, but there are alternatives. The rest of this article will be proposed alternative solutions to the use of returnable packaging.

Figure 2 Example of VCI bag

The first solution to replace the current one is the use of a corrosion protection pouch that can be used repeatedly in place of disposable VCI bags. An example of such a package is reusable VCI cover made by Australian producer Daywalk [18]. This product is made of PVC and contains volatile corrosion inhibitors. It is durable, resistant to rain, dust and UV radiation, and for better tightness it can be closed with a zipper or Velcro. Depending on the dimensions and customer preferences, the prices of the cover may vary, but they start from around 195 euros. Opting for this solution would completely exclude single-use packaging from the process of preparing products for shipment, but would require a significant initial investment.

Figure 3 Example of Daywalk Reusable VCI Cover

Another reusable packaging that could be used in the process are containers for transporting engines by Endural LCC [19]. These packages are made of high-density polyethylene, which is characterized by high strength and durability at a relatively low weight (approx. 25 kg). The containers can be stacked and are equipped with internal straps that provide additional protection for the product. Polyethylene alone is not enough to protect engines against corrosion, but the manufacturer offers the use of Static Intercept technology, which can successfully provide it. Static Intercept consists in fusing plastic with copper particles, which react with the elements causing corrosion and prevent its formation [20]. The approximate price estimated on the basis of the manufacturer's information is 185 euros. An appropriate number of this type of containers could replace not only the VCI foil, but also other packaging used so far - pallets and adapters.

Figure 4 Engine Cases - made by Endural

Deciding on the choice of packaging requires taking into account the financial factors and additional benefits for the company. For the purposes of the analysis, 55,000 engines shipped monthly (average for 2020) were assumed, packaging prices estimated on the basis of manufacturers' data (which may vary due to additional requirements, the scale of orders, negotiations) and the need to have 24,000 returnable packaging units to realize the flow (which found based on the number of adapters the plant currently has at its disposal). An important element was also the fact that single-use VCI bags are only purchased for 6 months a year when the products are most exposed to corrosion. The comparison of the existing solution with the proposed alternatives is presented in Table 1.

For a reliable calculation of the use of returnable packaging, the method of returning returnable packaging between delivery links should be analysed as another factor for the calculation. In the case of the described company, the costs of transport were not included, because the lorries go to Volkswagen Motor Polska sp. z o.o. in Polkowice to get the engines without any cargo or with pallets and adapters, so organizing additional processes would not be necessary.

Table 1 Comparison of packages for transporting engines

Package type	Engine Cases (Endural)	Reusable VCI Cover (Daywalk)	VCI bags
Unit price	€185	€195	€4
Demand in 1 year	24 000	24 000	330 000[1]
Costs in 1 year	€4 440 000	€4 680 000	€1 320 000
Approximate percentage of packaging consumption	5% for year	20% for year	100% for year
Additional benefits	- preventing the formation of packaging waste, - replacement of previously used packaging (less returnable packaging in the chain), - lower gross weight of the engines shipped, - greater durability.	- preventing the formation of packaging waste, - replacement of previously used packaging (less returnable packaging in the chain), -easier way of transport between the links of the supply chain (take up less space).	- no need for rotation between the links in the chain.

Table 2 Calculation of the implementation costs of selected returnable packaging solutions

	Engine Cases (Endural)	**Reusable VCI Cover (Daywalk)**	**VCI bags**
Base material			
Number of engines shipped monthly	**55 000**	**55 000**	**55 000**
Number of direct packages in monthly turnover	24000	24000	55000
The use of 1 year	24000	24000	330 000 (55 000x 6 months)
Approximate level of use	5%	20%	100%
Consumption for 1 year taking into account the level of consumption	25200	28800	330000
The cost of 1 piece	€185	€195	€4
The total cost of the basic material for 1 year	€4662000	€5616000	€1320000
Additional costs			
Pallets - need for 1 year	0	4000	4000
Consumption level for 1 year	0	0,05%	0,05%
Number of pallets for 1 year taking into account consumption	0	4002	4002
Average cost of 1 transport pallet – metal	0	€220	€220
Total pallet costs for 1 year	0	€880440	€880440
The period of consumption	0	15 years	15 years
Adapters - need for 1 year	0	24000	24000
Adapters- 1 year consumption level	0	0,10%	0,10%
Number of adapters for 1 year taking into account consumption	0	24024	24024

[1] 55,000 packages are used for 6 months a year (in autumn and winter).

Average cost of 1 adapter	0	€25	€25
Total adapters costs for 1 year	0	€600600	€600600
The period of consumption	0	15 years	15 years
Total cost of additional materials for 1 year		€1481040	€1481040
Total product cost	€4662000	€7097040	€2801040
The period of consumption	5 years	5 years	for only one use

The table 2 presents an analysis of the implementation costs of three returnable packaging solutions for transporting engines for Volkswagen Motor Polska sp. z o.o. in Polkowice. There are three solutions:

- **Engine Cases (Endural) -** do not require any additional equipment. The engines are only transported in the described containers. Can be stored in layers during transport.
- **Reusable VCI Cover (Daywalk) -** requires the use of pallets and adapters to prevent motors from moving. There are 6 engines on the palette.
- **VCI bags -** form only one use. They are disposed of after use, requires the use of pallets and adapters to prevent motors from moving. There are 6 engines on the palette.

Table 3 presents the costs of implementing the above 3 solutions for the described enterprise. The period of 5 years was adopted due to the longest wear of the material Engine Cases (Endural). The analysis covers the costs of implementation: purchase of packaging, its consumption (damage, loss) and replenishment per year, purchase of additional materials (pallets and adapters). The analysis took into account the consumption time suggested by the packaging manufacturer.

Table 3 Analysis of the implementation costs of the proposed solutions

EUR	Engine Cases (Endural)	Cumulative costs	Reusable VCI Cover (Daywalk)	Cumulative costs	VCI bags	Cumulative costs
Costs including years	4662000		5616000		1320000	
	0		1481040		1481040	
start	0	4662000	0	7097040	1320000	3021040
1st year		4662000	1040	7098080	1321040	4342080
2nd year		4662000	1040	7099120	1321040	5663120
3rd year		4662000	1040	7100160	1321040	6984160
4th year		4662000	1040	7101200	1321040	8305200
5th year		**4662000**		**7101200**	1320000	**9405200**

Considering the financial aspect, reusable packaging requires a significant initial investment, but brings long-term benefits. The analysis of the implementation of the presented 3 solutions for the use of returnable packaging shows that the most advantageous will be Engine Cases (Endural), then Reusable VCI Cover (Daywalk), and the least currently used VCI bags solution.

Analysing the costs of implementation and application of these solutions should be checked at which point reimburse the cost of the proposed alternative solutions in relation to their current solutions. For this purpose, a cumulative cost analysis was used. This has been shown in Figure 5.

It should be noted that the first solution will pay for itself in the 15th month. The second solution will pay off only in the 38th month. Due to the fact that the company operates a delivery system using VCI bags, it was decided to analyse an additional variant. This analysis did not take into account the purchase costs of pallets and adapters, as they are already purchased and used at Volkswagen. Figure 6 shows this solution.

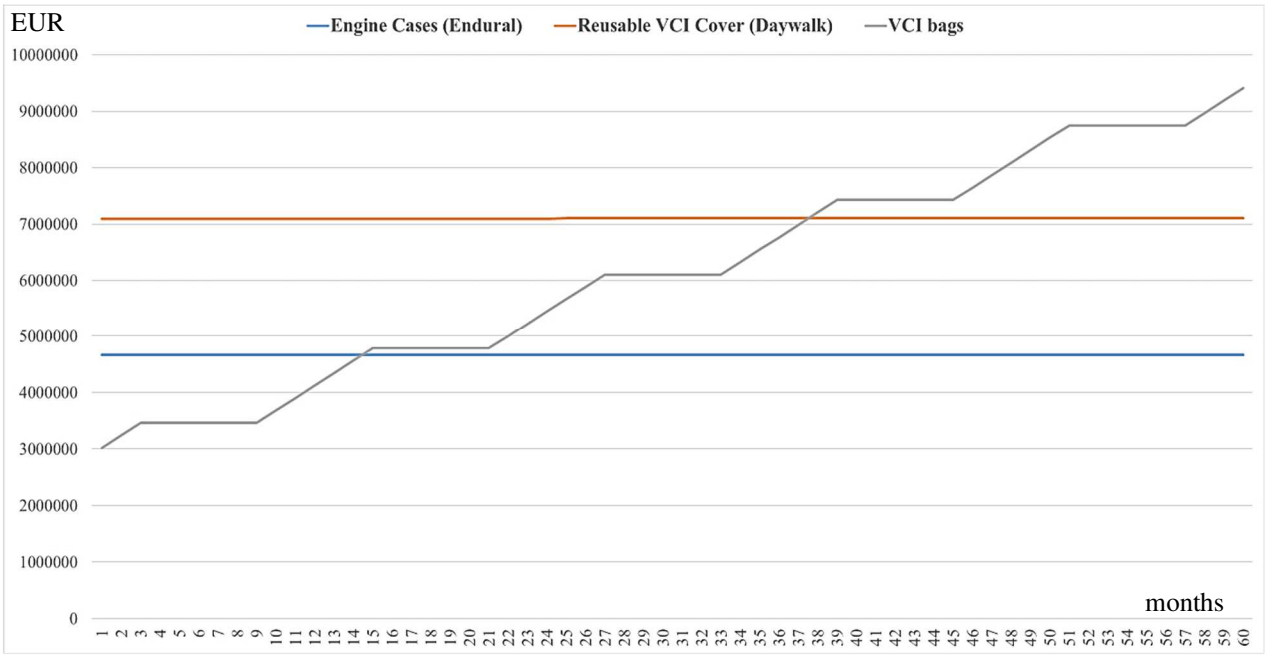

Figure 5 Cumulative costs of implementing returnable packaging solutions

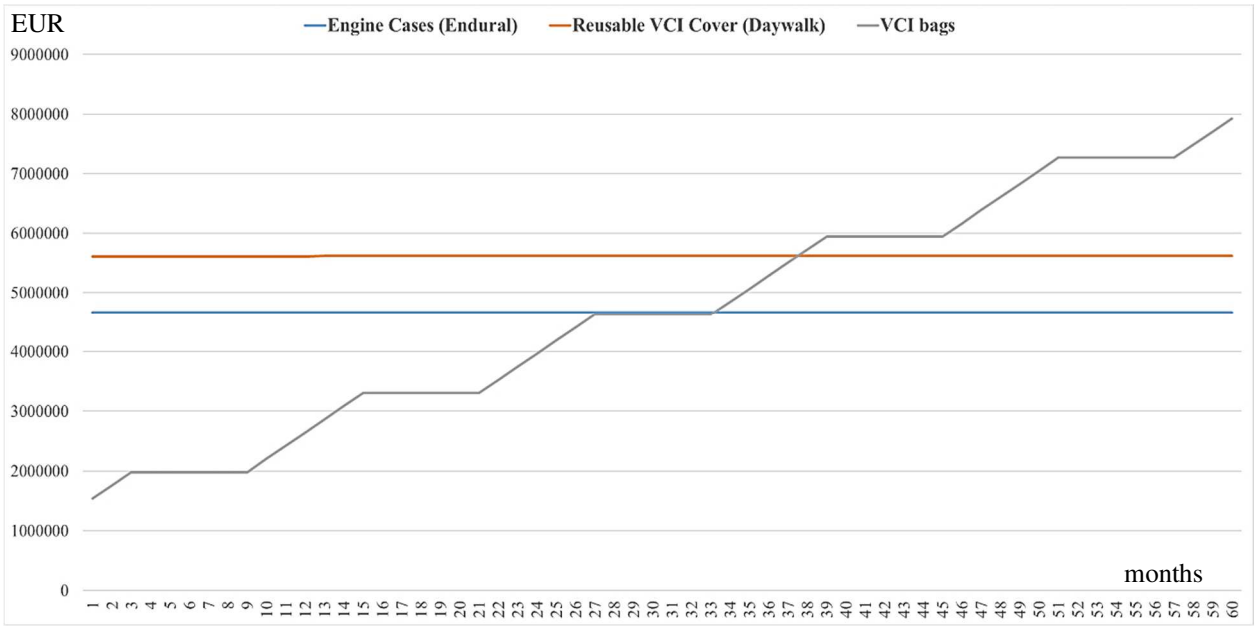

Figure 6 Cumulative cost analysis without taking into account the purchase costs of pallets and adapters

In the current situation where the pallets and adapters are in the company, the return on investment will be in the 34th and 38th months.

The financial criterion should not be the only determining factor in changing the packaging used in the enterprise. Their functional characteristics, the number of returnable packaging in the chain and compliance with the principles of sustainable development are also important. In terms of environmental protection, disposable VCI bags, generating approximately 330,000 pieces of packaging waste per year, are the least favorable. Both proposed alternatives become waste at the end of their life cycle, but there are definitely fewer of them (engine cases - 30,000, VCI covers – 48,000 every 5 years). In relation to the number of reusable packaging in the chain, currently around 24,000 adapters and 4,000 pallets are required for the flow. Managing the largest number of packages would be required when using Reusable VCI Cover (24,000 adapters, 24,000 covers and approx. 4,000 pallets), and the smallest (24,000 units) with the introduction of Engine Cases, which would replace all previously used packaging. Another feature that distinguishes the Endural container is

its low weight. Currently, cargo weight is one of the main characteristics limiting the number of engines transported in a single trip. A maximum of 15 pallets corresponding to a weight of 22,065 kilograms are loaded per truck. Each pallet contains 6 motors and 6 protections - adapters. The weight of such a set is 1471 kg, of which 397 kg is the weight of the packaging itself. Using Engine Cases, the engine with packaging would weight 204 kg, the 6 engines 1224 kg, and the 90 (maximum quantity currently shipped) 18,360 kg. A difference of 3705 kg to the present solution would allow 18 more engines to be loaded, which is also dimensionally feasible considering that the containers can be stacked.

After analysis, it can be concluded that Endural Engine Cases are the most cost-effective choice. Using these packages instead of the current solution would have long-term financial benefits, reduce packaging waste and the amount of packaging in the chain, and could make it possible to transport more engines on a single course. The second proposition, Reusable VCI Covers, would also pay for itself, but it is not that profitable due to the need to manage as many as 52,000 packages in the chain, which could reduce flow efficiency and generate additional costs.

5 Conclusion

The article presents the process of using returnable packaging in supply chain management. The description was based on a case study of Volkswagen Motor Polska sp. z o.o. The effective process of using returnable packaging in the process of product flow between the links of the supply chain is undoubtedly very important. Both in terms of cost reduction for individual companies and environmental impact. The study identified a process in which it is possible to replace disposable packaging with returnable packaging. It is the stage of shipping and transporting products between the links of the supply chain. In addition, a cost analysis was carried out for the use of 3 different types of packaging, which differ in cost, strength, consumption level and the number necessary for shipment. The most effective form of returnable packaging is plastic packaging - Endural Engine Cases, created for a specific order and transport of products. It is much cheaper to operate within 5 years, moreover, its weight is much lower than the currently used method of transport. Reusable covers with a zipper or Velcro are in second place. The last and the most expensive solution is currently used with VCI bags. They are disposable, but necessary in transport due to the possibility of corrosion of the finished product, which is the engine. The article identifies and analyses the possibility of using returnable packaging in the process of preparing shipment and transport of finished products in the automotive industry. The analysis should be extended to the costs of transporting the containers themselves back to the company. In this case, they were not taken into account, because the cars, without a load or with current reusable packaging, go for a product ready for Volkswagen Motor Polska sp. z o.o. This is another argument for the use of returnable packaging, thanks to which we will save on disposable packaging and the transport will be used effectively.

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IMPACT OF HALAL STANDARDS ON LOGISTIC EMPLOYEE PERFORMANCE

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Keywords: Halal Standards, 3PL Halal Logistic, Employee Performance, Performance Management, Islamic Work Ethic
Abstract: Halal market size was predicted to grow to 3.2 Trillion dollars in 2024. Many countries, including Indonesia, have a strategic plan for this huge market opportunity. The Indonesian government asked organisations that produce Halal products to adopt Halal Standards is compulsory. Still, there are many internal factors that organisations need to consider to begin the implementation. One of these factors is related to the diverse workplace and the performance of an employee. This research aims to understand and analyse the effect of Halal Standards and performance management on employee performance with work motivation as an intervening variable and Islamic work ethic as moderator. The data collection was captured by distributing a questionnaire to Third Party Logistic Halal certified floor staff employees in two centres of Halal Supply Chain in Indonesia located in West and East Java. These Halal centres are diverse religious workplaces. The sample determination is done through Random Sampling, and the analysis technique uses Partial Least Square (PLS). The results showed that Halal Standards, work motivation and performance management have a significant impact on Employees Performance. Work motivation mediated Halal Standards and performance management on employee performance, but Islamic work ethic is not a moderator between work motivation and employee performance. The results are also interesting because, even though Halal Standards are Islamic rule, there is no significant issue to adopt it on 3PL with a diverse religious workplace.

1 Introduction

Halal is an Islamic rule that needs to be followed by a 1.9 billion Muslim world population. Halal means permitted. All Halal products and services will be allowed for Muslims to consume. The halal market has grown significantly in the last decade. The global Halal industry is estimated to be worth around USD 3.2 Trillion in the next two years. It grows annually around 20 percent or about USD 560 billion a year. It will be a great opportunity for the organisation to serve this market. Islamic work ethic will be related with Halal because the implementation of Islamic rule or standards should be for the whole process in the organisation, including ethical work. It is called Kaffah, the Arabic word for whole or totally, to describe Islamic practice in each activity [1]. On the other side, a modern organisation that adopt diversity gains many benefits, such as performance improvement and competitive advantages [2].

Halal status is not only because of using Halal raw material but also during production and logistic process, the product is free from Non-Halal items contamination, and it means that status of a product can be changed from Halal to Non-Halal (Haram) if the logistic process does not comply with Halal Standards. There are many differences between Halal logistics and conventional logistics. It means that when conventional 3PL decided to implement Halal Standards, they need to change some business processes and also allocate a budget for employee Halal training [3], need proper training to avoid the struggle of operation [4], the cost is higher than conventional logistics [5]. Still, the market opportunity is also very big, not only for the Muslim population who willing to consume Halal products related to religious believe, but also Non-Muslim who are interested in consuming Halal products for various reasons, such as quality [6], food safety [7], Hygiene and cleanliness [6], environmental friendly [7] and animal welfare [8].

It also needs to consider that a diverse workforce may have an issue with religious needs. [9] argued that religion may become a future diversity issue in the company. Besides the diverse workplace, as an organisation, 3PL Halal logistics also need to consider internal factors, such

as employee motivation and performance management. Work motivation will be critical to evaluate because Halal Standards need employee involvement [10]. Also, due to the high-risk responsibility to comply with tight standards, like Halal and responsibility to achieve performance as a service company, it may impact emotional exhaustion [11]. [12] informed that implementation of Halal Standards makes employees unable to work optimally, but other researchers found that standards have a positive impact on employee productivity and job outcomes. [13] stated that Halal Standards of food could improve job outcomes in sharia hotels.

Based on the above review, we have below research question:

1. Does Halal Standard and performance management have a significant and positive impact on employee performance in the 3PL religion diversity workplace?
2. How is the effect of work motivation on the performance of an employee in 3PL religion diverse workplace?
3. What is the role of Islamic work ethic in the employee's work motivation in a 3PL religion diverse workplace?

2 Literature review

2.1 Halal Standards

Halal Standards may be various in different countries, but basically, it will need to follow the Holy Quran and Hadith of the Prophet Muhammad. The Indonesian government issued a law and regulation of Halal No 33 of 2014 that stated of compulsory all Halal products must have Halal Certification, except for Non-Halal products. Effective September 2019, this regulation started to be applied to a food product. The scope of regulatory Halal Standards in Indonesia consists of eleven criteria [14], including (a) Halal Policy (b) Halal Management (c) Training and education (d) Halal Raw Material (e) Halal Product (f) Halal Production Facilities (g) Written Critical Activities (h) Tracking Capability (i) Handling Non-Halal Items (j) Internal Audit and (k) Management feedback.

There is limited previous research for the topic of Halal Standards impact on employee performance, but much prior research about other types of standards had been done to evaluate its impact on performance, such as [15] found that business process standardisation improved process time, cost-saving and quality. [16] found a positive impact of 5S standardisation on employee and organisation performance. [17] found that green standardisation impacts performance. Based on those previous research, we can find many positive effects of standardisation on performance.

2.2 Performance Management

3PL Halal logistic, as a service company, has an agreed target performance contract with the customer. They will become a part of the whole customer process of the product lifecycle from manufacturing to end customers. Performance management includes training, performance appraisal, recognition, salary or benefit and performance dialogue or management feedback. Performance management goal to ensure the organisation can achieve its objective. For 3PL, it means to meet the logistic contract performance. There are many reasons why 3PL Halal certified need performance management, for example, to manage proper training, ensure accuracy and objective performance measurement and minimised turnover ratio. Halal logistics need a specific skill that should be trained properly. According to [18], Halal training faced many issues, such as various different types of training programs and a lack of structured training programs. The high turnover rate also creates issues and challenges for the organisation. It means that the organisation should allocate costs for training a new hire. Organisation also needs to provide objective, fair and transference performance appraisal to motivate employees, therefore managing performance management is crucial for employee performance, according to [19] human resources effected significantly to productivity performance. The human factor aspect is crucial to consider in the design of logistic and production systems [20,21].

2.3 Motivation

One of the main duties of a manager is to motivate his employees. Unmotivated employees will have lower productivity and below the target of performance. Herzberg's theory is the best method to predict job satisfaction [22]. Herzberg proposed the Two-factor Theory of Motivation, the motive factor that creates employee satisfaction and the hygiene factors that may create job dissatisfaction [23]. In 3PL Halal logistics, there are many hygiene factors that need to be managed properly by the manager, such as company Halal policy and working conditional, which is different from conventional logistics, but there are also motive factors, like the work itself, responsibility and growth. The employee in this business will work to produce Halal products that can be categorised as high quality, clean, and safe [24] will make employees proud and also an opportunity for growth that they can advance their careers with valuable Halal skills and knowledge.

Previous research topic in motivation on employee performance proved that motivation in the form of rewards has a positive effect on performance [25], positive affect on employee productivity [26] and motivation also reduce turnover intention [27].

2.4 Islamic Work Ethic

Ali developed the Islamic Work Ethic scale and tested it on 150 Arab students for reliability and validity [28]. These measures have been used by many researchers, such as [29], who used it to analyse the relationship between computer work ethic and job satisfaction, [30] for

organisational culture and work environment, [31] for innovation capability and [32] for its impact on job outcome. [33] found that Islamic work ethic moderated job satisfaction on accountant performance.

2.5 Employee Performance

Logistic activities, especially for floor staff, consist of motion and timely activities. Taylor introduced the time and motion measured method to calculate performance [34]. Using this method, employee performance will be calculated by comparing the target time to do a task with the actual time an employee can achieve. This time and motion method is now common practice in many largest companies [35].

As a service provider, 3PL Halal logistic needs to ensure each employee work based on Halal Standards, it means that performance below or above the target should be investigated for possible issue in quality and safety. If staff is working by following the procedure, then the target should be similar to others who also follow the same procedure. Bell Curve or forced ranking is the method for performance measurement that can show performance based on the normal distribution curve [36]. Ideally, most employees will be in the middle of the normal distribution curve.

Based on the above discussion, we proposed below hypothesis:

H1: Halal Standards affected positive and significantly on employee performance
H2: Performance Management affected positive and significantly on employee performance
H3: Work Motivation effected positive and significantly on employee performance
H4: Work Motivation mediated Halal Standards on employee performance
H5: Work Motivation mediated performance management on employee performance
H6: Islamic Work Ethic moderated work motivation on employee performance

3 Methodology

3.1 Samples

Sample of this research was collected from 163-floor staff employees of 3PL Halal certified logistics in two centres of industrial area in Jababeka, Cikarang, West Java, Indonesia and Rungkut, Surabaya, East Java Indonesia. These organisations are diverse workplaces in religion, gender and race:

3.2 Method of Analysis

Analysis of the data used in this research was inferential statistical analysis, namely Partial Least Square Structural Equation Model, referred to as PLS-SEM. This analysis was operated through the Partial Least Square (PLS) software, version 3.3.3 of Smart-PLS. Figure 1 below is a research framework with Hypotheses in each path.

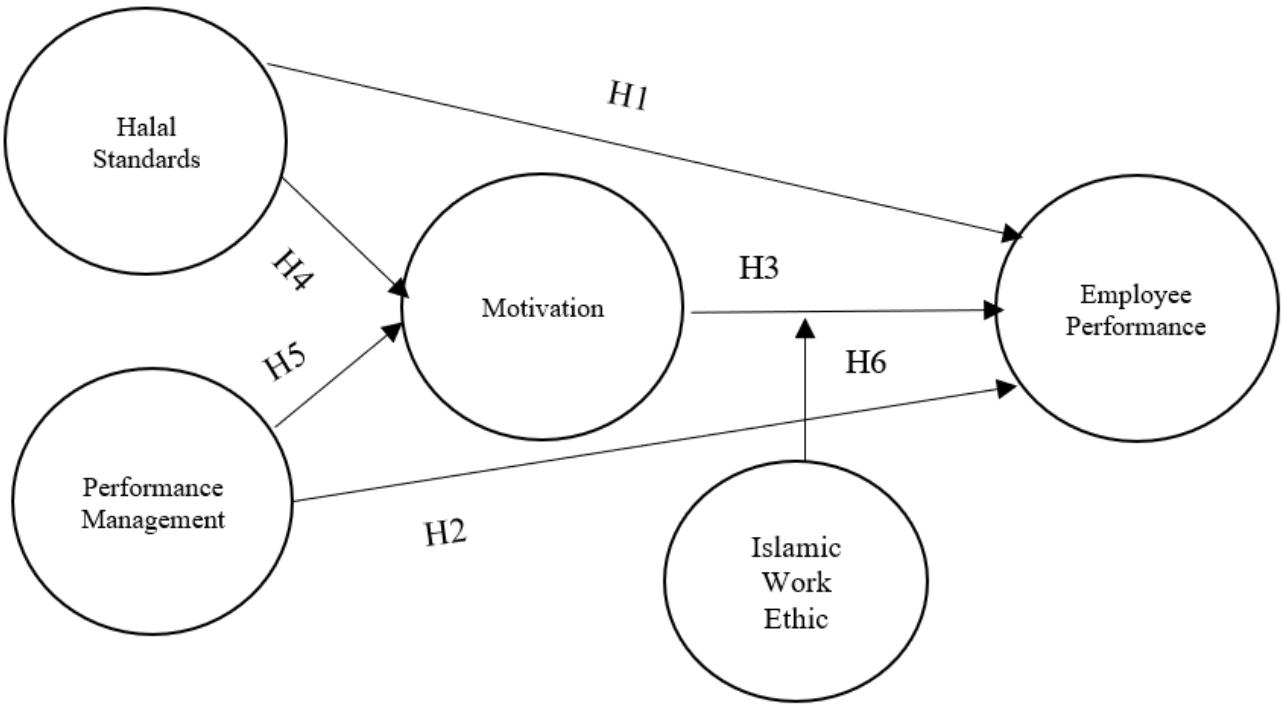

Figure 1 Research Framework [authors]

Partial Least Square-Structural Equation Modelling (PLS-SEM) has been increasingly used by many business researchers to the explained variance of the dependent construct [39]. Data was tested with outer and inner model testing to ensure the quality of data before being processed for hypotheses testing. The outer model tests are validity and reliability test. Average variance Extracted or AVE was used for convergent validity testing that can be achieved if all variable in the model is significant statistically. The equation of AVE as below

$$\Sigma \kappa^2 / n \quad (1)$$

where K is the loading factor for each item and n is the number of items in the model.

Reliability testing was using Cronbach's Alpha and Composite reliability values. The aim of this reliability testing is to ensure that items are consistent to measure across time. Below is the Cronbach Alpha equation

$$\alpha = (k \times \bar{c}) / \bar{v} + (k\text{-}1)\, \bar{c} \quad (2)$$

where k is the number of scale items, $\bar{c}$ is average covariances between all items, and $\bar{v}$ is average each items variance

4 Result and discussion

4.1 Validity Test

According to [37], the indicator is valid if the loading factor is 0.70 or higher. Validity testing for the model uses minimum Average Variance Extracted (AVE) with an accepted value is 0.5 [38,39]. Testing using the convergent validity of the measurement model with a reflective indicator is assessed based on the correlation between the item score/component score with the construct score calculated by SEM-PLS. [39] argues that an indicator can be said to have good validity if the loading factor value is greater than 0.70, while the loading factor of 0.50 to 0.60 can be considered sufficient. The validity test calculations showed in the following Table 1. Based on the value in Table 1, all variables have an AVE value of >0.5. The result has met the criteria of convergent validity so that all indicators are valid and can be used for further analysis.

Table 1 Result of Validity Testing

No	Variable	Average Variance Extracted (AVE)
1	Islamic Work Ethic	0.784
2	Employee Performance	0.640
3	Performance Management	0.758
4	Work Motivation	0.548
5	Halal Standards	0.563

Source: authors computation

4.2 Reliability Test

Reliability testing uses Cronbach alpha and Composite reliability. [39] argued that Cronbach alpha value should be above 0.7, composite reliability value should be 0.6 until 0.7 [39]. Table 2 below shows Cronbach's alpha and composite reliability, all variables in both parameters have values above 0.7. Thus we can conclude that all variables are reliable.

Table 2 Result of Reliability Testing

No	Variable	Cronbach's Alpha	Composite Reliability
1	Islamic Work Ethic	0.986	0.986
2	Employee Performance	0.720	0.842
3	Performance Management	0.920	0.940
4	Work Motivation	0.924	0.935
5	Halal Standards	0.934	0.943

Source: authors computation

4.3 Data analysis results: direct effect testing and indirect/mediation effects testing

Reliability testing uses Cronbach alpha and Composite reliability. [39] argued that Cronbach alpha value should be above 0.7. According to [39] composite reliability value should be 0.6 until 0.7. Table 2 below shows Cronbach's alpha and composite reliability. All variables in both parameters have values above 0.7. Thus we can conclude that all variables are reliable.

Table 3. Below is the result of direct effect testing, where IWE is Islamic Work Ethic, PM is Performance Management, HS is Halal Standards, MV is Work Motivation, and EP is Employee Performance.

Table 4. Below is the result of indirect effect testing for mediating the impact of motivation in the relationship between performance management and Halal Standards with employee performance.

Table 3 Result of Direct Effect Testing

	Original Sample (O)	Sample Mean (M)	Standard Deviation	T Statistics	P Values
IWE -> EP	-0.094	-0.101	0.099	0.949	0.343
PM -> EP	0.298	0.306	0.096	3.112	0.002
PM -> MV	0.179	0.178	0.071	2.531	0.012
MV -> EP	0.489	0.483	0.085	5.760	0.000
Moderating Effect 1 -> EP	0.045	0.046	0.056	0.797	0.426
HS -> EP	0.192	0.198	0.097	1.975	0.049
HS -> MV	0.539	0.546	0.065	8.233	0.000

Source: authors computation

Table 4 Result of Indirect Effect

	Original Sample (O)	Sample Mean (M)	Standard Deviation	T Statistics	P Values
PM -> MV -> EP	0.087	0.087	0.038	2.289	0.023
HS -> MV -> EP	0.263	0.263	0.053	5.002	0.000

Source: authors computation

Based on the value of path coefficient and *T* statistics, the effect is significant if the path coefficient is more than 0.1 and *T* statistics is more than 1.96 with a *p* value less than 0.05 [40]. Hypotheses H1 was accepted, Halal Standards has a positive and significant effect on Employee Performance of 3PL Halal Certified Logistic. It means that organisations can gain better employee performance with Halal Standards implementation. This result is similar to other studies that analyse employee performance improvement after implementation of quality, OHSC and 5S standards [16,41,42]. However, this study contributes to the currently limited literature about Halal Standards impact on employee performance. It also can be concluded that Halal Standards are similar to other standards in terms of reducing the complexity of working, variation and result in deviation.

Hypotheses H2 was accepted, Performance Management has a positive and significant effect on employee performance. It means that an organisation needs performance management to support employees for better performance. All functions of performance management, such as training, performance appraisal, recognition, and salary and management feedback, will be needed to manage employee performance. This result is similar to other previous research from [43,44].

Hypotheses H3 was accepted. Work Motivation has a positive and significant effect on employee performance. It means that employees need the motivation to improve their working performance. Motive factors, particularly the work itself, increase the motivation of employees to do their best in their job. Doing an honoured job to provide Halal product make employee proud. On the other side, a well manages working condition as the impact of standardisation also improve employee motivation. This result is similar to previous research, for example, research from [46] that found salary increase, overtime allowance and pay holiday are motivational tools for employees in manufacturing. This result also is aligned with previous research for Herzberg two motivation factors that motive factors can increase job satisfaction.

Hypotheses H4 and H5 were accepted. Work motivation is also an intervening variable for Halal Standards and performance management on employee performance. This finding is aligned with many previous types of research about work motivation as the intervening variable for various variables on the performance and productivity of employees [47].

Hypotheses H5 was not accepted. Islamic work ethic does not moderate motivation on employee performance. This result is different from the previous study from [33] who analyse Islamic work ethic as a moderator of job satisfaction on employee performance. The difference in these findings is likely due to the differences in job characteristics of respondents. In this study, the participants are blue collar employees who need to follow job procedures and supervisors' instructions. The previous study's participants are accountants, white-collar employees that have different job characteristics.

5 Conclusions

Based on data analysis, several conclusion of this study as follow below:

1. Halal Standards has a significant and positive impact on employee performance, and the original sample value is 0.192, confirmed that the path is positive. It

means that the adoption of standards and consistency to comply with criteria can improve the performance of the employee.

2. Performance Management has a significant and positive impact on employee performance. The original sample value is 0.298, the confirmed path is positive. This means that proper performance management implementation, including accuracy, transference and objectivity of performance appraisal, will help the employee to perform better.
3. Work Motivation has a significant and positive impact on employee performance. The original sample value is 0.489, the confirmed path is positive, and the value is more than the original sample of Halal Standards and performance management. This result concluded motivation is crucial for a leader to improve the performance of the employee, particularly in the working environment that runs a tight standard, like Halal. The leader can facilitate improvement in motive factors and managed hygiene factors to ensure employees are always in high motivation.
4. Work Motivation mediated Halal Standards on employee performance. Based on the indirect effect result, T Statistic is 5.002. It means that Halal Standards adoption increase the motivation of the employee and its impact on better performance. Complying with all standard criteria increases staff work motivation, for example, regular internal audits and production facilities. The implementation of this standard makes the working environment always clean, manageable and tidy because organisations need to maintain a working environment with no waste to ensure the product is free from contamination of non-halal material. This clean, tidy and well-managed working environment also reduces the hygiene factor in motivation theory which is a factor that can decrease employee morale.
5. Work Motivation mediated Performance Management on employee performance. Based on the indirect effect result, T Statistic is 2.289. It means that proper performance management impacts work motivation and makes an employee perform better in their job. Performance management, including training and accuracy in performance measurement, will increase employee motivation. Proper training will increase employee skill in Halal logistics, and accuracy of performance measurement will drive the motivation of employees because they know that their performance will be calculated fairly and objective.
6. Islamic work ethic is not a moderator between work motivation and employee performance. Based on the *T* statistic value indirect effect is below 1.96, which confirms that not significant. This result is different from other studies, most likely because the population of this study is blue-collar employees, while the previous study is mostly white-collar staff. Islamic work ethic should be scale based on job characteristics. Compared with the previous study, one indicator that has a gap is the creativity scale, which is not a dominant factor for employees who need to follow standards carefully, like Halal Standards. Employee's creativity might have risk if they did their job in a different way with the criteria of the standard. Therefore consistency to follow the work procedure is crucial for this kind of business.
7. This study also confirms that there is no significant issue for a diverse religious organisation to implement Halal Standards. The organisation is still able to perform better. Therefore organisation does not need to change the diversity of its staff.

Based on the conclusion above, the suggestion that the author can make is that third-party logistics should consider implementing Halal Standards because there is a huge market opportunity for this market. Internally company also gain benefits from the improvement of employee performance.

6 Implication

Some practical and theoretical implications for this study as below

1. Halal Standards adoption has multiple advantages, but to gain the benefit of this standard adoption, organisations need to ensure all related parties in the organisation follow the standard criteria properly.
2. The organisation should implement information technology as a tool to ensure the proper implementation of performance management. Performance appraisal as part of performance management needs to be accurate, transference and objective to help the employee to perform better.
3. Intrinsic motivation is crucial to keep the employee in high motivation. In order to maintain that intrinsic motivation, leaders should understand how to motivate employees. This study affirmed that employees are proud to work in an organisation that provides Halal products to customers. Therefore leaders should use this motive factor to improve the working spirit of the employee.
4. It is suggested to implement Islamic Work Ethics based on the job characteristic.

7 Limitation

Similar to others, this study also has a limitation, particularly the object of this research is 3PL Halal Certified logistics only. It will be interesting to study also other logistics types, for example, in-house logistics, so we will have the comprehensive result for the impact of Halal Standards on logistic employee performance.

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MONITORING THE CONGESTION OF URBAN PUBLIC TRANSPORT SYSTEMS FOR THE POSSIBILITY OF INTRODUCING THE CROWD SHIPPING DELIVERY IN BRATISLAVA

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Keywords: urban public transport, crowdsourcing, visual study, passenger flows, crowd shipping
Abstract: The aim is to study the congestion of urban passenger transport in the historical part of Bratislava for the possibility of introducing crowdsourcing technology. The visual methods of examination are used in work. According to the results of the study, data were obtained on the congestion of urban passenger transport and its distribution by hours of the day at the entrances to the historic part of the city. The obtained results indicate the possibility of using crowd shipping technology in off-peak periods. Monitoring of public transport flows in the urban core will identifying the distribution of travellers and contribute to understanding the time window for implementing crowd shipping technology during the day, minimal whit influence on the other participants of the transport process. The peak traffic load is observed on the routes passing through the Slovak National Rebellion (SNP) square in direct downtown of the city, from 8 am to 9 am and from 4-6 pm in the evening, and from 7 am to 8 am in the morning and 5-6 pm for the routes passing through the SNP bridge across the river Danube. A new way to monitoring the number of passengers in public transport was suggested. The paper provides credits for future development sharing technology and sustainable development of transport in Slovakia. The results could be usfull for transport policy and regularities for local government in Bratislava in case of apply new delivery technology.

1 Introduction

The intensive growth of urban freight transport leads to numerous transport links, due to which such problems arise as traffic congestion, congestion on highways, an imbalance between the need for transport services and the real capacity of roads, and the negative environmental transport impact. In order to optimise traffic flows, there is a need to develop new methods of green logistics [1]. The constant growth of urban freight transport exacerbates several problems, such as the creation of a rational system of traffic organisation, ensuring the quality of public transport services, and environmental protection. Currently, the growth rate of freight transport is significantly ahead of the growth rate of the construction of new and reconstruction of existing highways in Bratislava [2]. As a result, there is a need to address the management of traffic flows to reduce their impact on the safety of road users, reduce the load on the road network, improve the environmental situation [3]. The functioning of the urban public transport system can be improved through the introduction of new technologies such as crowd shipping [4].

Crowdsourcing is a quite new concept of first-last-mile delivery. The main difference from the traditional courier delivery is that it is not necessary to make an additional trip [1,5]. At the same time, overcrowding of urban passenger transport does not physically allow its use due to the loading capacity of the vehicle. To implement the

crowdsourcing technology, it is necessary to assess the availability of passenger transport during peak hours, when it is the busiest.

Purpose: The study is aimed at monitoring the congestion of urban passenger transport for the possibility of introducing crowdsourcing in Bratislava.

The article consists of the following sections:

- analysis of research on crowd shipping and monitoring of urban passenger transport congestion;
- substantiation of the method of monitoring the congestion of urban passenger transport;
- analysis of the central part of the city to determine the location of the counter;
- conducting research and analysis of results;
- conclusions.

1.1 Literature review

In on-demand urban transportation systems, it becomes extremely important to think about advanced solutions for sustainable urban transport development. Urban logistics, especially in the last mile, has been the most expensive element of the supply chain. In the context of economic transactions, this refers to the use of an object (physical good distribution or service), the consumption of which is divided into separate parts. These details are shared in Client to client networks, which are coordinated through online community-based services or through intermediaries in Business to client models [6-8]. Uber, Zipcar, Blablacar and Airbnb are trend-setting companies trying to change society by using our resources more sustainably. A recent survey of consumers in the United States found that the economies of sharing in the travel, car-sharing, finance, human resources, and music and video streaming sectors increased their revenues from $ 15 billion. US up to 335 billion dollars. The USA in the following years [9].

The development of urban transport complexes in the modern sense is divided into economic, social and environmentally sustainable development, taking into account its impact on the economy, man and environment, effects (outside transport) [10]. It should be noted that the positive effect of the development of transport systems is created by reducing the total socio-economic damage in all areas of the national economy. As a result, the development of urban transport should take into account its "social value", assessment all costs for all modes of transport (including an individual), as well as losses due to noise, air pollution, time, loss of urban territory that can be used with greater benefit; energy consumption and deaths in road accidents, etc [2,6]. Shared mobility is seen as a promising way to reduce road congestion and any emissions [5,6]. In their paper, [7] defined sustainable development as «a process of change in which the use of resources, investment directions, technological progress, and institutional change are in harmony and provide opportunities to meet human needs now and in the future». The literature offers a number of case studies [8,9] on the impact [10], road behaviour [11-13] comparing car-sharing systems [14], technical documents on how to coordinate and manage the overall mobility [1,15]. Shared mobility is also a new concept that includes many new models. Two features common to all of these services: an element of the asset (vehicle) sharing instead of ownership, and that they rely on technology [16-19]:

Furuhata et al. [20] identified three main problems for agencies that provide joint travel for passengers. These are the development of attractive mechanisms, the correct organisation of the trip, and gaining trust among passengers in online systems. Thus, overall mobility should be able to compete with direct access to end-to-end transport provided by private cars [21,22]. Sustainable development of transport requires the development of activities that will lead to the greatest economic and social benefits while reducing negative environmental losses. Similarly, in the long run, the sustainable development of transport is complex and involves enormous challenges, dilemmas, difficulties, and barriers: migration, internal mobility, ageing, urbanisation and globalisation [23,24].

Minken et al. [25] include the urban cultural heritage and the accessibility of goods/services in urban freight zones as sub-targets. Methods of sustainable transport development are aimed at improving urban mobility in order to ensure access and rapid movement of the population in large urban centres [26]. Urban transport is usually associated with many modes of transport, and public transit can be carried out using different modes of transportation. Quak [27] advocates for the support of sustainable transport that provides accessibility and mobility (electric buses in combination with high-speed vehicles are more efficient alternative in terms of energy consumption instead of using regular private cars).

Existing methods of inspection of passenger flows can be classified according to a number of features. Thus, according to the duration of the period covered by the survey, there are systematic and one-time surveys [2]. Systematic is carried out daily during the entire period of operating online via Intelligent Public Transport System sensors: infrastructure [28], smartphones [29], smart vehicles [28]. Short-term research aimed to specific objects and was limited in time and parameters.

Previously, the attitude of Bratislava citizens to become a crowd-shipping courier was analysed [30]. Factors influencing the potential willingness to be non-professional couriers in Bratislava were established [30,31]. Moreover, freight demand for the Old Town of Bratislava was surveyed [29]. The businesses loyalty to use crowd shipping solutions was assessed. Deciding on the issue of new types of services, it is necessary to comprehensively assess their pros and cons in the urban public transport system and other related systems. To make optimal decisions, a systematic analysis of the research object, a clear understanding of the technological process, effective organisation of the interaction of participants, fast information updates, optimal service management,

determination of system constraints [32] are required. One of the most important links in the design of new types of services in cities is to determine the patterns of traffic flows and their distribution over sections of the road network. Monitoring of public transport flows in the urban core will identifying the distribution of transport correspondence of travellers and contribute to understanding the time window for implementing crowd shipping technology during the day, minimal whit influence on the other participants of the transport process. Literary analysis shows the absence of methods for monitoring the congestion of urban public transport systems for the possibility of introducing crowd shipping delivery. Therefore, this paper has discovered this topic.

2 Methodology

For the successful integration of crowdsourcing into the urban public transport system of Bratislava, it is necessary to collect the initial data. Various data collection methods that can be used. These methods differ in complexity, in the types of information that can actually be collected, and in the level of interaction between the developer of the survey and the respondents in the survey. The method of visual inspection of the interior of the vehicle was used for the study. This method allows for the estimation of large volumes of vehicles with minimal error [31]. When located at observation posts, the counters estimate the crowding of passing vehicles on this scale:

1 point – passengers occupy less than half of the seats;

2 points – passengers occupy more than half of the seats, but there are still free seats;

3 points – all seats are occupied, and up to half of the standing places are occupied;

4 points – the vehicle is full of passengers, but it is still possible to enter it;

5 points – the vehicle is full and cannot be entered.

Recommendations for the application of the method emphasise that the most reliable information can be obtained when placing counters at bus stops when using the so-called «silhouette» method of estimating the cabin crowding.

From the information about the results of the visual inspection, it is possible to assess the occupancy of the vehicle and give recommendations on the possibility of delivery of goods in them at the considered hours. The study was conducted in the morning and evening rush hours.

3 Result and discussion

3.1 Analysis of the urban public transport system of Bratislava

First, the description of the transport system of the city has been made. Bratislava has the largest urban public transport network in Slovakia. A company belonging to the local government (Dopravný podnik Bratislava) carries out all the urban transportation [32].

Surveys of traffic flow in Bratislava show that the road network operates at the capacity limit, especially in the central part, and in some parts of the network is completely exhausted. The main reason for the difficult and negative transport situation in the city is the disproportion between the level of motorisation and the density of the road network, which also significantly affects the reduction of speed and increases the commuting time [4].

The possibility of using public transport along with the transfer of passengers to deliver goods, when possible, will use the available space inside the cabin for small loads (from documents to several pallets), without any damage to passenger transport and minimal changes in work schedules. Public transport is known to be on schedule, and its presence will not in any way affect the flow of traffic, not to mention freight transport. This will partially solve one of the main problems of modern Bratislava: to relieve the historic centre from road transport and traffic flows associated with the delivery of goods or significantly reduce their impact; increase the number of interested working people; caring for the environment, etc.

3.2 A visual study of urban passenger transport congestion

In autumn 2019, in the Old Town, Bratislava, a study of passenger traffic in the historical part of the city was carried out using the visual method. The Old Town was chosen as the study area. It is a relatively small pedestrian area, and almost all of Bratislava's main attractions are located there: on the left bank of the Danube, between the Old and New Bridges. And as it is the central part of the city, it has good transport links.

In Figure 1, the map shows the area where the study was conducted.

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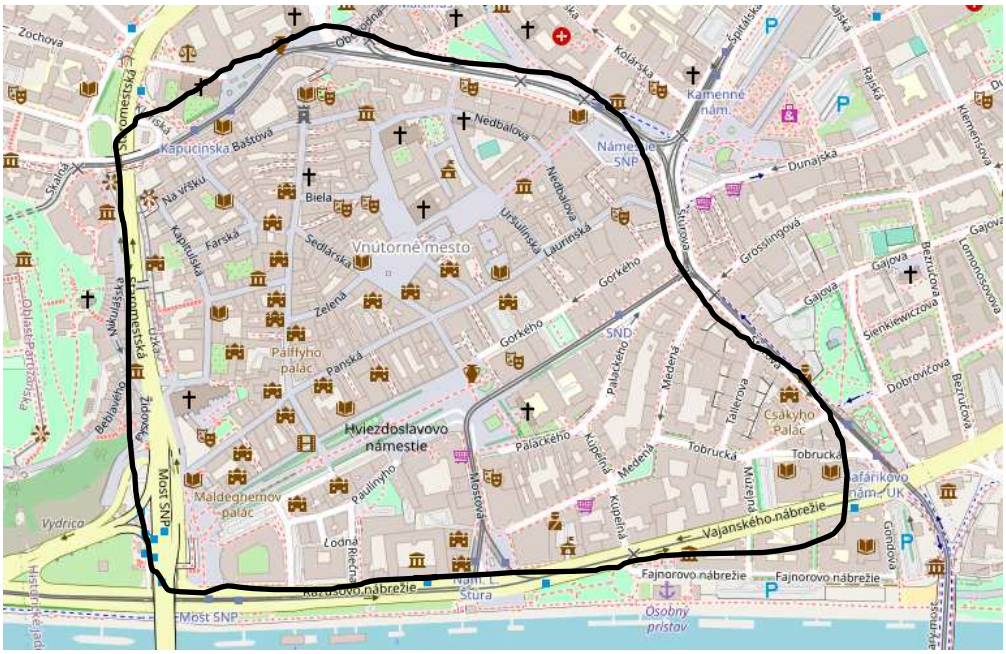

Figure 1 Map of the Old Town where the study was conducted

For the visual inspection, two bus stops were selected for the location of the counters, through which 90% of the routes in the central part of the city pass. For the visual inspection, the accountants were located at public transport stops, namely «Most SNP» and «Namestie SNP» for more efficient data recording. The selected points for fixing the crowding of the passenger transport cabin were selected taking into account the transport interchange of passenger modes of transport, location of stops, and the places of gravity for passenger traffic, and are presented in Figure 2.

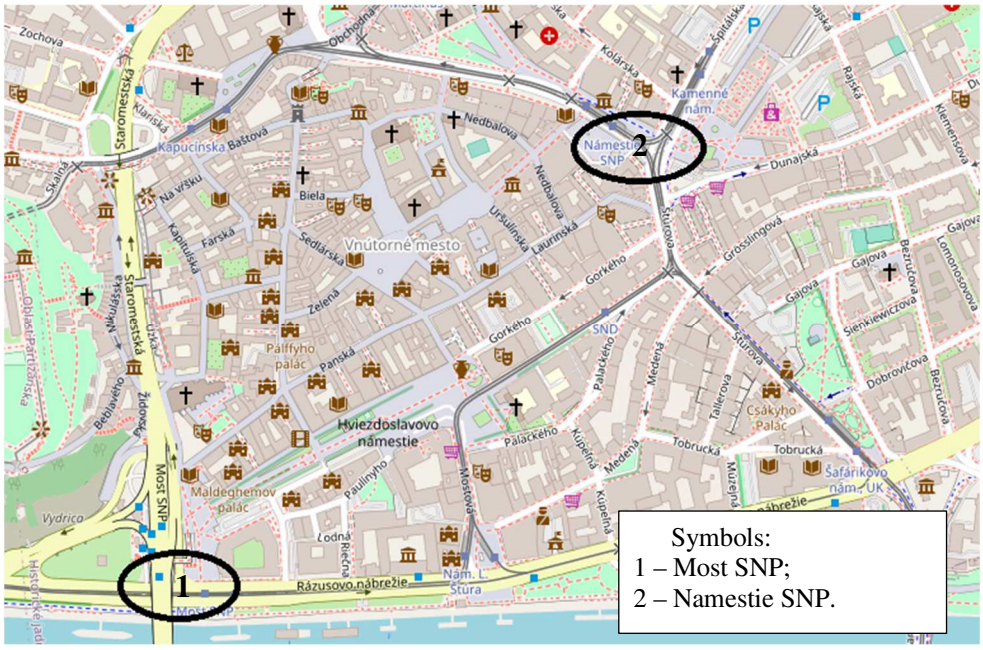

Figure 2 Public transport stops where a visual inspection was conducted

The visual method was used to compare the availability of transport during peak hours, i.e. to take into consideration the greatest load on the urban public transport system for more accurate data collection. Rush hours usually occur on weekdays when people move from their places of residence to work (from 7 am to 9 am) and back (from 5 pm to 7 pm). An example of a visual survey method is given in Table 1.

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Table 1 Log of visual inspection of passenger flows

Number of observations	Time of day, hour, min	Route number	Bus brand	Direction of movement	Cabin crowding (points)
1	6:51	1	Škoda 30T	Reverse	3
2	6:52	9	Tatra K2	Direct	2
…	…	…	…	…	…
1048	10:01	X6	Škoda 30T	п	1

Analysis of the results of the visual examination for Most SNP is shown in Figure 3, and studies for Namestie SNP are shown in Figure 4.

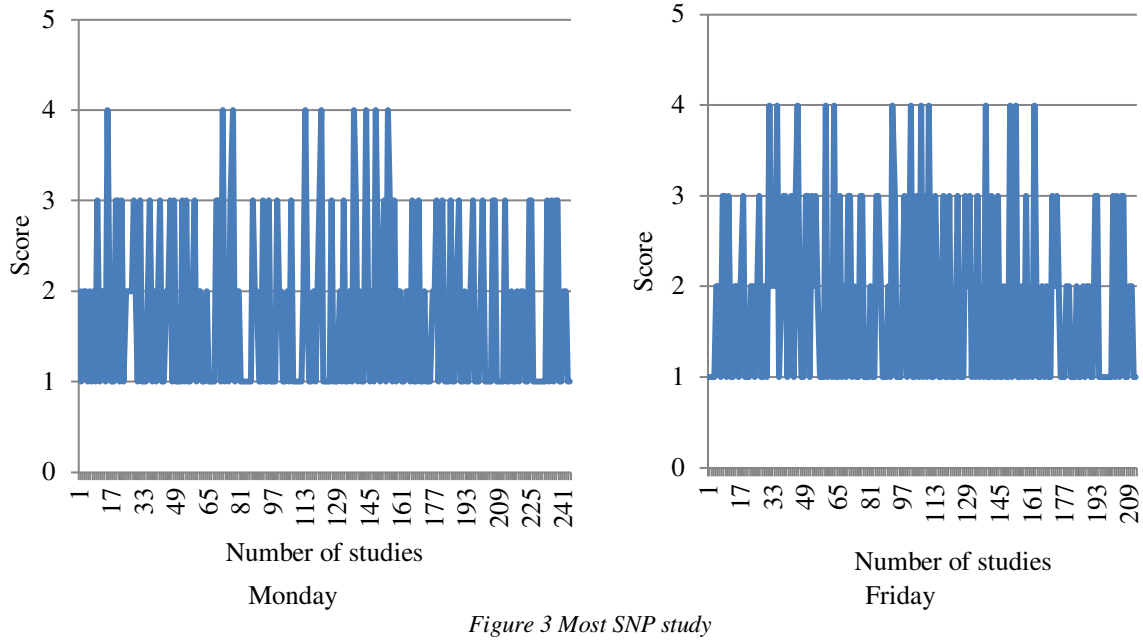

Figure 3 Most SNP study

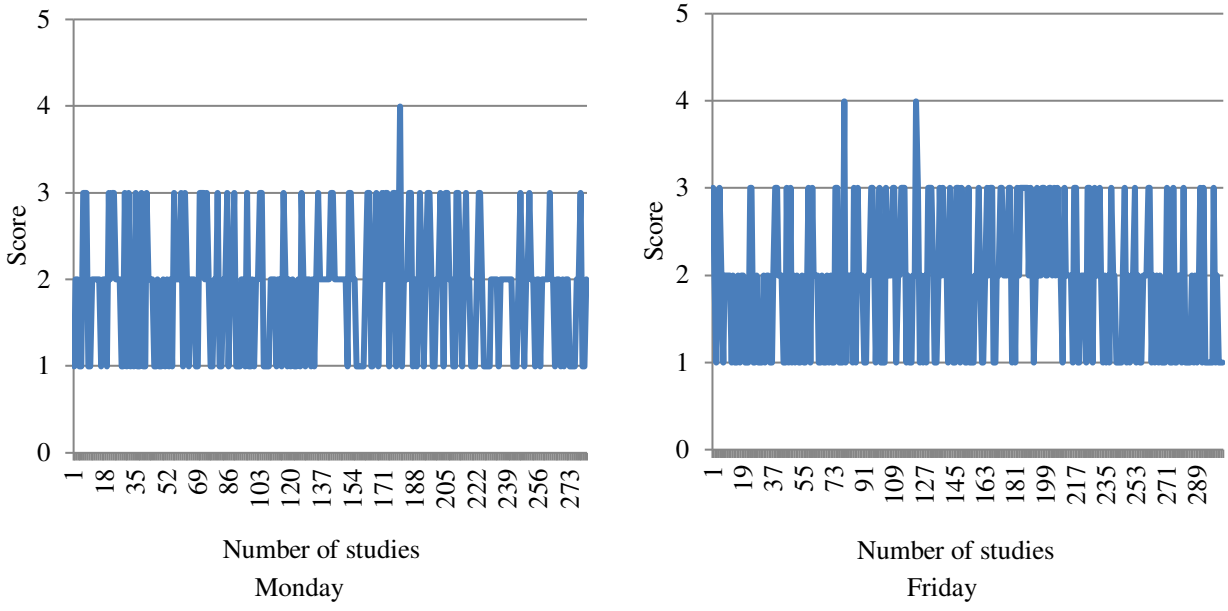

Figure 4 Namestie SNP study

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A total of 246 observations were recorded on Most SNP on Monday and 213 on Friday; on Namestie SNP: 305 and 284 observations, respectively. Monitoring of urban passenger traffic congestion showed that Most SNP area is busier than Namestie SNP. At this stop, the load level of 4 points was observed almost 4 times more often.

In the next step, we will determine the weighted average value at each stop within an hour. Monitoring of the urban passenger transport congestion is shown in Figure 5 and Figure 6.

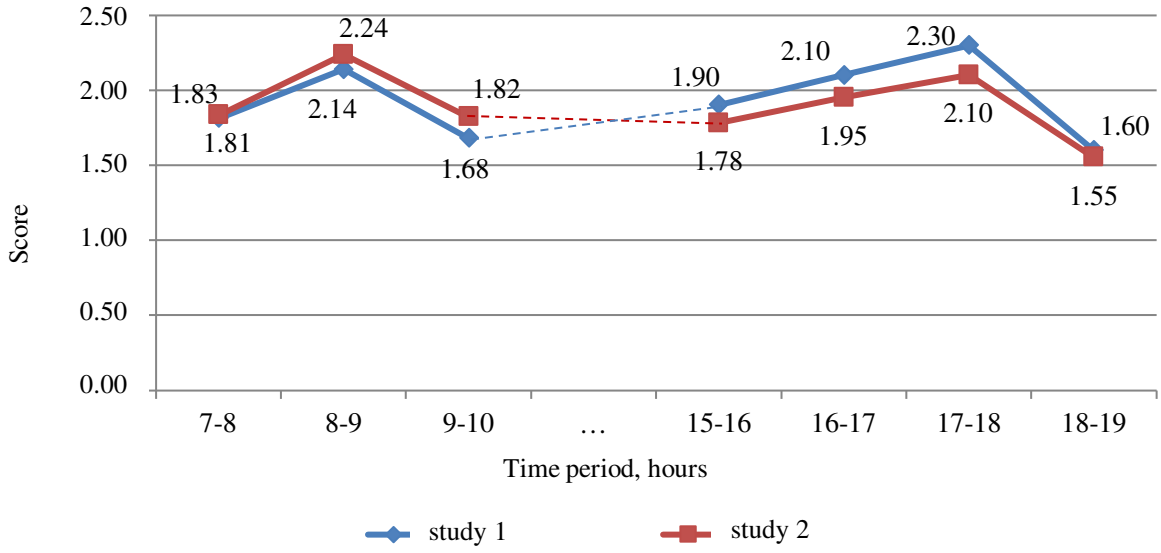

Figure 5 Change in vehicle crowding in the morning and evening rush hours (Namestie SNP)

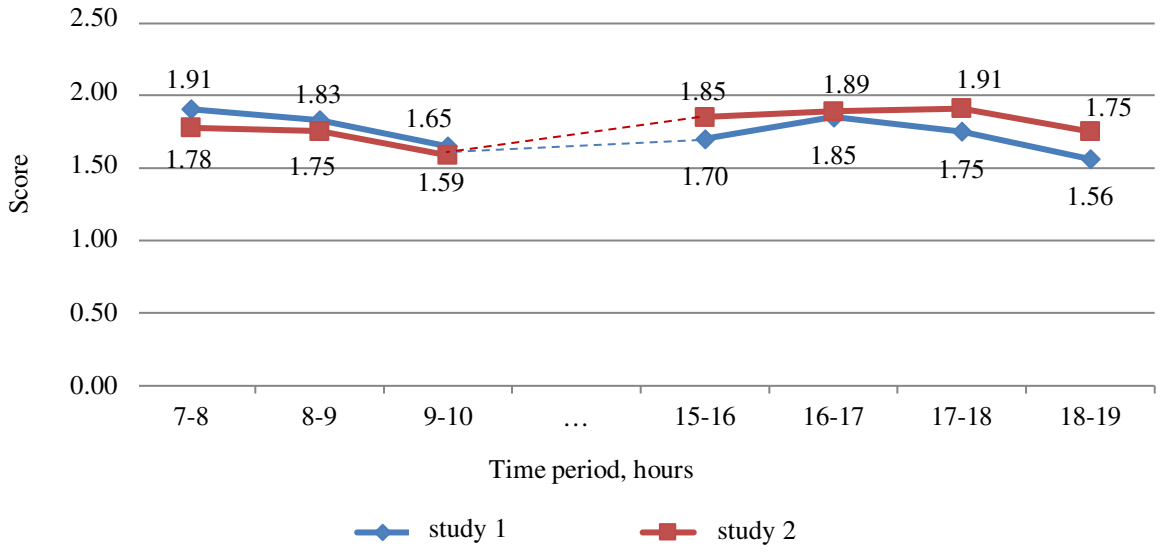

Figure 6 Change in vehicle crowding in the morning and evening rush hours (Most SNP)

Analysis of Figure 7 shows that the peak load of public transport is observed from 8 am to 9 am in the morning and 4-6 pm in the evening. At this time, it is not advisable to perform delivery in this direction, as the cabin of the vehicles is crowded.

Analysis of Figure 8 shows that the peak load of public transport is observed from 7 am to 8 am in the morning and 5-6 pm – in the evening. The load level on the routes passing through Most SNP is lower.

4 Conclusions

The results of the project are aimed at solving the transport problems of the historical part of Bratislava. The creation of a new freight delivery system will not limit the possibility of using existing schemes but will be a

supplement or alternative to it. The availability of additional options will give more flexibility in making decisions about the maintenance of the historical centre of Bratislava.

The obtained results of Fig. 5-8 indicate the possibility of using crowd shipping technology in between peak periods when the crowding of passing vehicles do not exceeds 2 points on the suggested scale in the methodology section when passengers occupy more than half of the seats, but there are still free seats. This level would be optimal for less making disturb of other passengers and suddenly raising of passenger flow on station to level 3. The peak load of public transport is observed on routes passing through Namestie SNP from 8 am to 9 am in the morning and 4-6 pm in the evening. In this period, 3 and 4 points of crowding inside of vehicles was observed. The peak of urban transport loading is observed on the routes passing through Most SNP, and the smaller peak of urban transport loading is observed from 7 am to 8 am in the morning and 5-6 pm in the evening.

The range of data presented covers the real traffic data in Bratislava, on Monday and Friday – the most overloading days. At the same time, the ridership may vary depending on the day of the week, holidays, etc., which will affect the level of traffic. The presented approach expands the knowledge on monitoring the congestion of urban passenger transport for the possibility of crowd shipping and presents new principles of planning sustainable urban development. Monitoring of public transport flows in the urban core will identifying the distribution of transport correspondence of travellers and contribute to understanding the time window for implementing crowd shipping technology during the day, minimal whit influence on the other participants of the transport process. The visual methods of examination have their drawbacks. In particular, it does not allow to accurately determine the parameters of passenger traffic but only allows to visually assess the vehicle crowding rate of on the routes. With the help of this method, data on the occupancy vehicles on sections of the route can be obtained, but it does not allow to establish the actual volume of transported passengers on the route as a whole and the nature of the correspondence. Visual observation can be performed, as well, by drivers or conductors, who are issued the appropriate table. This method is used mainly in the sample survey. Visual methods do not provide continuous observation and are limited by human factors, accuracy, reliability. Automated methods (e.g. ITS [28, 29]) provide processed information about passenger traffic without involving people in the direct collection of such information. The choice of specific methods for surveying passenger traffic is made based on the objects of the survey and the tasks solved on the basis of its results, taking into account local conditions, the availability of funds and the possibility of attracting resources to conduct it and process the data. Due to this, the visual method applying would be enough to obtain preliminary results on the possibility of introducing the crowd shipping delivery in Bratislava. More detailed results could be obtained in further studies on this issue.

The paper provides credits for future development sharing technology and sustainable development of transport in Slovakia. The results could be usfull for transport policy and regularities for local government in Bratislava in case of apply new delivery technology.

In the future, it is advisable to survey potential crowd shipping couriers to determine the patterns of time of their trip to the central part of the city and to establish the relationship between the traffic congestion and mobility of residents.

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IMPACT OF PRIVATE TRANSPORT ON THE ENVIRONMENT AND SOCIETY IN THE CONCEPT OF CITY LOGISTICS AND LIFE CYCLE ASSESSMENT
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IMPACT OF PRIVATE TRANSPORT ON THE ENVIRONMENT AND SOCIETY IN THE CONCEPT OF CITY LOGISTICS AND LIFE CYCLE ASSESSMENT

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Keywords: smart city and city logistics, life cycle assessment, the impact of cars on the environment, electric and hybrid-cars, sustainability development
Abstract: Changes taking place in the economy generate negative consequences for the environment and society. This is the case of, inter alia, agglomerations. In recent years, the concept of city logistics has been developed, the aim of which is to draw attention to sustainable development in urban agglomerations. There are many studies on the advantages of ecological means of transport, but they do not show the impact on other environmental factors. This is undoubtedly a research gap that needs to be explored. The article presents the idea of city logistics and the impact of private transport on agglomerations. Introducing new, innovative solutions in the field of private transport, such as electric cars and hybrids, does not have a positive impact. The article presents statistics on the number of cars in relation to the ecological ones. Moreover, with the help of the SimaPro program, their environmental and social impact was analyzed. The analysis was enriched by participant observations, consisting of the analysis of the number of means of transport and their use in one of the Polish cities. The aim of the article is to present the impact of passenger transport on the environment and social life. The analysis was carried out on the basis of three countries with similar economic development: the Czech Republic, Poland and Slovakia.

1 Introduction

Europe is a highly urbanized area. The vast majority of Europeans live in cities, which has an impact on the natural environment. The development of the agglomeration contributes to more and more interference in the landform by the need to expand residential buildings along with the supply infrastructure - where new housing estates are built. There are also roads, sidewalks, service buildings and public places. Larger agglomerations are also accompanied by greater traffic, especially passenger cars. As a consequence, it is worried about high air pollution in city centres, transport congestion, excessive noise and long travel times. This has a negative impact on the quality of life of the agglomeration's inhabitants and the attractiveness of a given region. Due to the emission of harmful compounds into the atmosphere, the authorities of the European Union are implementing projects aimed at reducing the number of passenger cars, especially those with internal combustion engines, in favour of public transport, electric cars or plug-ins. These are the tasks related to, inter alia, with the removal of diesel transport from the city centre. They are, to some extent, related to urban logistics. The aim of the article is to present the impact of passenger transport on the environment and social life. The analysis was carried out on the basis of three countries with similar economic development: the Czech Republic, Poland and Slovakia.

2 City logistics and passenger transport

The concept of urban logistics is defined by many authors. For example, M. Szymczak defines urban logistics as the process of planning the implementation and control of flows: initiated outside and directed to the city, initiated in the city and directed outside, passing through the city, internal in the city, and the accompanying information flows, aimed at meeting the city's needs in terms of quality of management, quality of life and development" [1]. On the other hand, Szołtysek defines the city's logistics as "all processes of managing the flow of people, cargo and information within the city's logistics system, in accordance with the city's development needs and goals, respecting the protection of the natural environment, taking into account that the city is a social organization whose primary goal is to meet the needs of the city. its users" [2].

Flows in cities affect the quality of life of their inhabitants. That is why it is so important to implement measures aimed at reducing the negative effects of transport and making urban transport options more attractive for passengers, and thus reducing the emission of harmful substances from passenger transport [3-5]. J. F.

Ehmke described these projects as taking steps to create a travel system in the city, which would have a positive impact on travel time, but also on the level of harmful emissions [6]. Transport is responsible for the emission of greenhouse gases at the level of about 20%, and therefore, due to its high impact on the natural environment, the EU authorities have implemented numerous legal regulations to reduce the scale of the negative impact [7]. These can include, among others 2011 White Book of Transport, which envisages a significant reduction in greenhouse gas emissions by 2030 and the elimination of combustion vehicles from cities by 2050 [8] and the "Green Deal" from 2019, which assumes that by 2050 Europe will become the world's most completely neutral continent for the environment [9]. The transport congress and the regulation of city traffic is one of the goals of the city's logistics concept. Actions taken by city authorities should also be consistent with the maintenance of sustainable development and the quality of life of the inhabitants, and the attractiveness of the region for investors.

3 Methodology

LCA (*Life Cycle Assessment*) is a method of assessing the life cycle of a product, which describes the impact of a given product on the environment, analyzing its life cycle from the moment of raw material extraction, through production, use until its end of life and handling a given product as waste. All recommendations for the product life cycle assessment are regulated by ISO 14000 standards (from 14040 to 14049) [10]. There are four interacting phases of the product life cycle assessment, the interrelationships of which are illustrated in the diagram below (Figure 1).

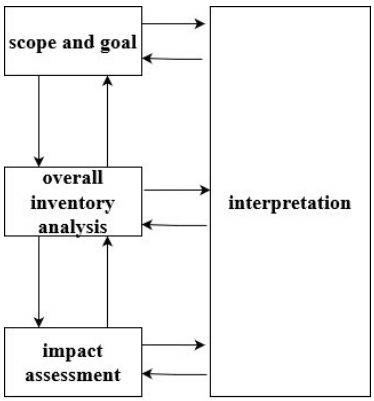

Figure 1 Four Stages of Life Cycle Assessment [11]

In the case analyzed in this publication, the product life cycle of passenger cars will be taken into account. The aim of the study is a comparative analysis of the environmental impact of passenger transport, taking into account the European exhaust emission standard and the type of fuel in accordance with the Eco Indicator 99 (E) procedure, which is used to determine the impact of the product on the natural environment. The resources of the SimaPro 9.1 program, developed by Dutch developers from PreConsultant, were used. Thanks to the use of the SimaPro software and the use of Eco Indicator 99, it will be possible to determine the impact of the analyzed means of transport. They will be analyzed in relation to eleven categories of impacts, which, grouped into groups, constitute three categories of damage. This division is presented in Table 1 below.

Table 1 Division of damage categories into impact categories

Impact category	Damage category
minerals fossil fuels	resources
the exploitation of the land acidification ecotoxicity	ecosystem quality
radiation the climate change inorganic compounds carcinogenic compounds organic compounds ozone hole	human health

Potential impacts causing damage are expressed in units depending on the damage category. For ecosystem quality, the unit PDF (*Potentially Disappeared Fraction*) is used, which is multiplied by a square meter of land and a year (PDF * m^2 * year). Damage caused in the human health category is expressed in the DALY unit (*Disability Adjusted Life Years*), while the damage in the resources category is expressed in MJ (Mega Joule), which refers to the possible use of additional energy to obtain the used raw materials [12].

4 Result and discussion

In order to adopt the appropriate parameters for the assessment of the life cycle of passenger cars in the SimaPro program, prior to the commencement of the research, the use of passenger cars in urban traffic was assessed using the empirical method. The measurement lasted 60 minutes. It was performed twice in the same location (Lwowska-Podgórna-Waryńskiego intersection in Zielona Góra), 2 hours apart on the same day. The same analysis was performed throughout the week (7 days). The following tables (2 and 3) present the average results for the entire week.

Table 2 Average number of car trips- study I.

Number of people in the car	Number of cars
1	344
2	96
3	20
4	4
5	1
Sum	**465**

Table 3 Average number of car trips- study II.

Number of people in the car	Number of cars
1	282
2	85
3	8
4	0
5	2
Sum	**377**

Table 2. was compiled from the results of the first observation. During the entire measurement, a total of 465 passenger cars were recorded. 344 drivers drove alone, which is 74% of the vehicles considered in the study, much less because 96 drivers travelled with one passenger (21%), there were three people in 20 cars (4%), and four travellers in four cars (0.7%) and 5 people (0.3%) were observed in only one car.

Table 3 is based on the results of the second observation. The total number of cars passing during the study was 377. 282 cars with one person (74.8%), 85 cars with two people in the vehicle (22.5%), 8 cars with three drivers people (2.1%) and two cars with 5 people inside (0.5%). During the second observation, no car with four people passed.

From the results obtained during the two observations, it was assumed that most passenger cars are transported only by the driver, which was taken into account when entering the input data to the SimaPro program.

4.1 Results of the LCA assessment of passenger vehicles

The aim of the study was to compare the impact of the life cycle of passenger transport using various fuels (petrol, diesel, gas), taking into account the European EURO exhaust emission standard (in the analyzed set, the EURO 3 standard is the oldest and least restrictive standard) and an electric passenger vehicle with regard to three categories of damage, which include: human health, ecosystem quality and resource consumption. It was assumed that each of the analyzed vehicles carried only the driver over a distance of 100 km. The results of the analysis are presented in the diagram below (Figure 2).

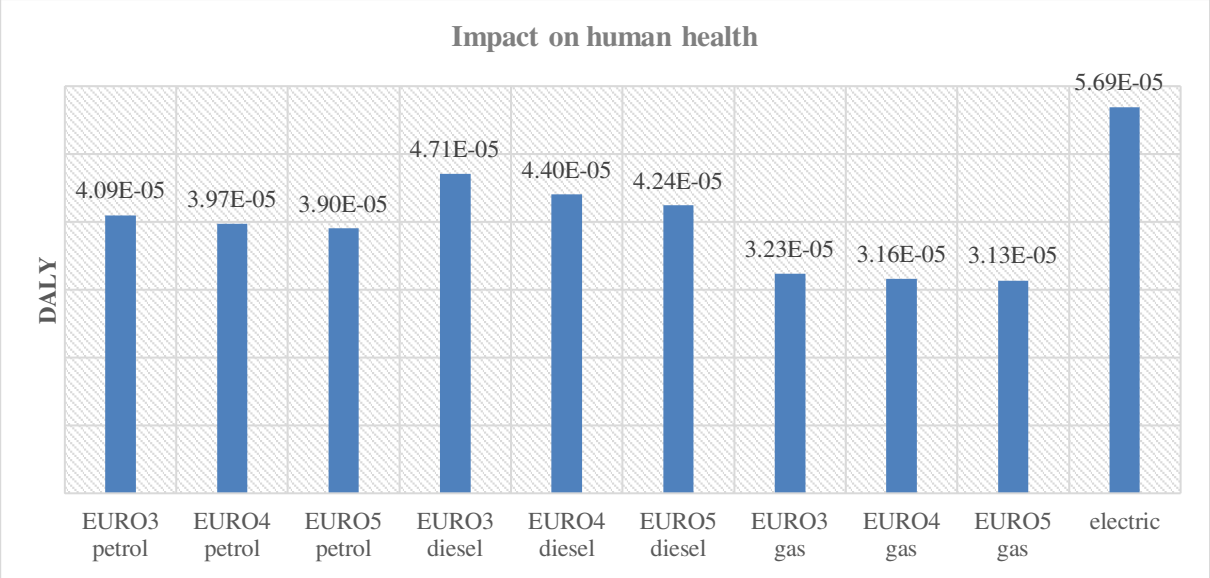

Figure 2 The impact of passenger transport on human health

The following conclusions can be drawn from this analysis regarding the impact of passenger transport on human health:

- The category of harm to human health takes into account the contribution of a given vehicle to harmful phenomena such as radiation, climate change, emission of inorganic, organic and carcinogenic compounds and contributing to the formation of an ozone hole.
- The conducted analysis shows that electric vehicles have the greatest negative impact on human health, while gas-burning vehicles that meet the requirements of the EURO5 standard have the smallest impact.
- In the case of internal combustion vehicles, the newer the vehicle is and meets the criteria of stricter exhaust emission standards, the less impact it has on this category of damage.
- Diesel cars are more harmful in their life cycle than cars that burn petrol or gas.
- The high degree of harmfulness of an electric car results from the formation of harmful compounds during the production of the battery necessary for the operation of such a vehicle. The battery consists of, among others, from the cathode and anode, which includes graphite, which negatively affects the air. In the battery production process phase, among others, PM_{10} dust,

nitrogen oxides NO_x and sulfur dioxide are emitted [13]. The harmful dust includes, for example, benzo(a)pyrene that negatively affects the quality of the inhaled air or dioxyne, which have a negative effect on the quality of water.

- In the case of electric cars, the fact of the origin of the electricity used to charge the batteries of this type of vehicle is not without significance. If energy is produced from coal, the negative impact of electric vehicles on human health is greater.
- Vehicles burning petrol in their life cycle emit mainly solid particles with a soot content with a diameter of not more than 2.5 µm, which negatively affect the quality of the inhaled air. Particulate matter contributes to the formation of harmful dust that causes respiratory diseases. Gasoline vehicles also emit carbon dioxide and nitrogen oxides, which have a negative impact on climate change. Arsenic is also emitted, the presence of which in the air and in water can cause severe poisoning.
- Passenger cars with petroleum-burning engines, similarly to gasoline vehicles, emit harmful solid particles into the atmosphere with a diameter of less than 2.5 µm, but additionally emit more particles with a diameter of up to 10 µm compared to gasoline engines. Diesel vehicles also generate severe air pollution with nitrogen oxides and carbon dioxide during their life cycle. Water and the atmosphere are also polluted by arsenic emissions.
- Analysis for transport gas burning is similar to the results of the previous two combustion vehicles in terms of the type of destruction. Gas vehicles also emit particulate matter less than 2.5 µm in diameter, carbon dioxide and arsenic, albeit at a lower level than the other analyzed combustion vehicles.
- In newer types of combustion vehicles, in order to minimize the emission of harmful compounds, better and better filters are installed, whose task is to prevent emissions, e.g. particles into the air. For this reason, the newer the vehicle, the lower its harmfulness.

In the next step, the impact of passenger cars on the quality of the ecosystem was analyzed, as shown in Figure 3.

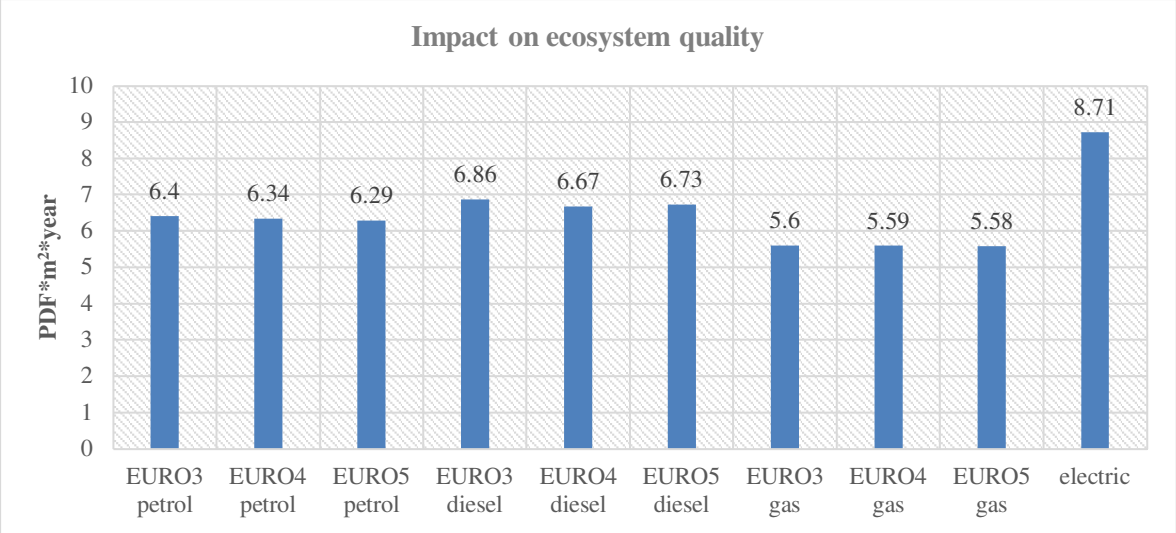

Figure 3 The impact of passenger cars on ecosystem quality

Several interesting conclusions can be drawn from the analysis of The impact of passenger cars on ecosystem quality:

- In the case of determining the impact of the product on the quality of the ecosystem, the impact of vehicles on such phenomena as acidification, ecotoxicity and land use was investigated.
- As assumed by the EcoIndicator 99 indicator, the electric vehicle exerts the greatest impact on the quality of the ecosystem in the analyzed case, while the gas combustion with the EURO5 standard has the least impact.
- According to the results of the analysis, electric cars in their life cycle generate large amounts of heavy metals such as zinc, which negatively affect soil, water and air. This type of vehicle also has a significant negative impact on aquatic organisms and the spatial layout of cities and suburbs due to the need to build the infrastructure required to use this type of vehicle, such as charging stations, but also factories, e.g. batteries or power plants, which produce electricity to power electric cars.
- The Eco Indicator 99 for gasoline and diesel vehicles identifies the main problem in this category as the emission of heavy metals such as copper that enter the waters (the share of gasoline at the level of 3.36 PDF * m^2 * year, diesel 3.56 PDF * m^2 * year). Occupation and wear of the road network, the transformation of

land for the extraction of raw materials and construction of new traffic routes were also identified as a problem for all analyzed combustion vehicles, which affects the topography.
- In the case of gas-burning vehicles, the transformation of land for mineral extraction was also distinguished.

The last aspect presented is the impact of means of transport on resources. The results and conclusions of the analysis carried out on the basis of the diagram (Figure 4) are presented below.

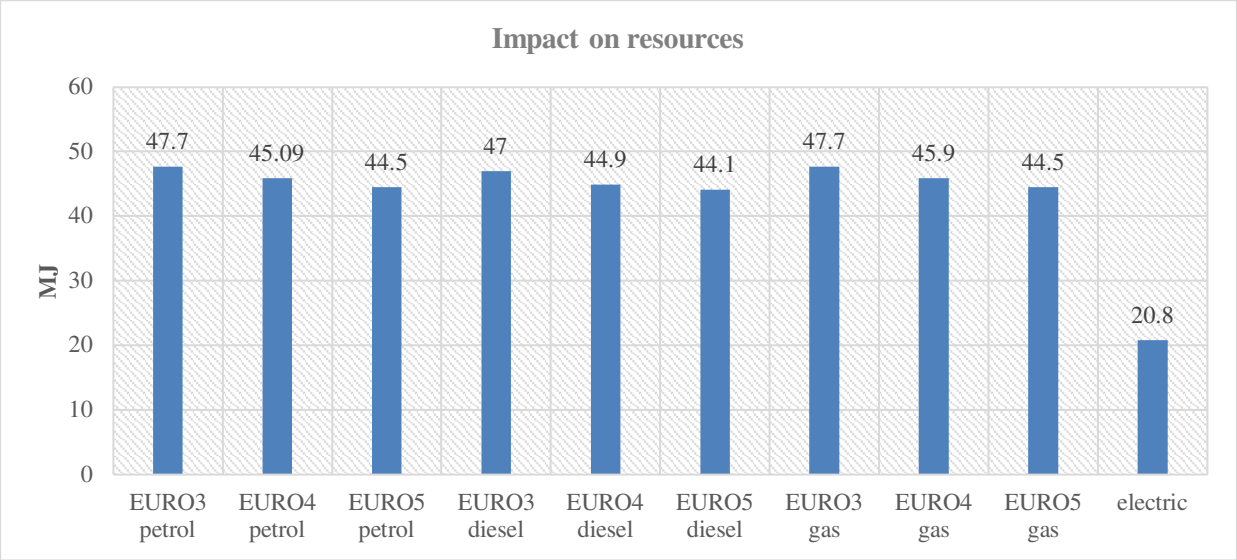

Figure 4 The impact of passenger cars on resources

The use of passenger cars and transport management in cities are related to environmental aspects. The chart (Figure 4) above shows the following conclusions about the resource impact of passenger cars:
- In the category of measuring the impact of products on resources, their share in the extraction of minerals and fossil fuels was taken into account.
- The results of the analysis for petrol and gas-fueled vehicles are very similar.
- Electric vehicles have the least impact, and diesel vehicles have the greatest impact.
- In the case of electric cars in this category of damages, they have the greatest impact on the process of gas and coal extraction, which are consumed by power plants that generate electricity to power the batteries of these vehicles. This impact depends on the method of obtaining electricity in a given area. These vehicles also affect the consumption of raw materials, including hard coal and lignite, and the consumption of copper, which is also used in the wires and systems of the power battery.
- Petrol and diesel vehicles negatively affect resources through the consumption of oil, natural gas and hard coal, which are part of the fuel.
- Passenger cars burning EURO5 standard gas have an impact on resources at the level of 44.5 MJ. In the case of this type of vehicle, they have the greatest impact on the consumption of natural gas, oil and hard coal.

In order to be able to better compare the analyzed vehicles and their total impact on the damage categories, the SimaPro program adopts the Pt unit, which means "one-thousandth of the annual environmental burden per one European inhabitant" [14]. Pt is an indicator that the SimaPro program is designed to illustrate the negative impact on the environment and thus on humans per capita. The normalized results of the analysis are presented in the table below (Table 4).

After normalizing the previously obtained results of the vehicle impact on the damage categories of the Eco Indicator 99, it is possible to identify the vehicles with the most negative impact on the natural environment. According to the Regulation of the European Parliament and of the Council on the approval and market surveillance of vehicles, the EURO 4 exhaust emission criteria have been in force since 2006, and EURO 5 has been in force since 2011 to 2015. The current standard is EURO 6, which was not included in the analysis. Converting the test results of three separate categories of damage to one unit showed that the oldest vehicles, i.e. those manufactured before 2006, are the most harmful when transporting a driver per 100 km by a passenger car. The electric vehicle also scores high due to its strong impact on human health and the use of resources. The obtained Pt levels prove that the newer the EURO exhaust emission standard, the more restrictive it is, thanks to which the vehicles have a smaller impact on the categories of damage.

Table 4 The impact of vehicles on the damage categories according to the normalized Pt unit

Vehicle type and Euro emission standard	Human health	Resources	Ecosystem quality	Total
Petrol – EURO3	1.85 Pt	0.448 Pt	1.7 Pt	3.998 Pt
Petrol – EURO4	1.8 Pt	0.443 Pt	1.64 Pt	3.883 Pt
Petrol – EURO5	1.76 Pt	0.44 Pt	1.59 Pt	3.79 Pt
Diesel – EURO3	2.13 Pt	0.48 Pt	1.68 Pt	4.29 Pt
Diesel – EURO4	1.99 Pt	0.466 Pt	1.61 Pt	4.066 Pt
Diesel – EURO5	1.92 Pt	0.471 Pt	1.58 Pt	3.971 Pt
Gas – EURO3	1.46 Pt	0.392 Pt	1.7 Pt	3.552 Pt
Gas – EURO4	1.43 Pt	0.391 Pt	1.64 Pt	3.461 Pt
Gas – EURO5	1.42 Pt	0.39 Pt	1.59 Pt	3.4 Pt
Electric	2.58 Pt	0.745 Pt	0.609 Pt	3.934 Pt

4.2. Use of private transport in selected countries

The movement of people is an inseparable element of their everyday existence. People migrate farther or shorter distances for work, education, or to meet their needs. Transport in cities is carried out using public transport, such as buses or trams, using pro-environmental solutions such as a city bike or scooter, or traditionally with the use of your own passenger car. The aim of the research is to present the dynamics of the use of private transport and its comparison between three European Union countries: the Czech Republic, Poland and Slovakia. For the purposes of this analysis, the following indicator was introduced:

$$NRV\left(\begin{matrix}\text{number of registered vehicles}\\ \text{per one resident of the country}\end{matrix}\right)=\frac{\text{the number of registered vehicles in the country}}{\text{the number of inhabitants of a given country}} \quad (1)$$

Where:
NRV – number of registered vehicles per one resident of the country.

The above indicator allows determining how many passenger cars, broken down by fuel type, are per one inhabitant of a given country. Thanks to the use of the index, it is possible to compare countries despite the different number of inhabitants and thus the number of registered vehicles. Unfortunately, due to the lack of up-to-date data in international databases, the years 2013-2019 were assumed for the analysis period. The data comes from the resources of the European Statistical Office and the Ministry of Economy of Slovakia. The value of the ratio of the number of registered vehicles per one resident of the country is presented in Figure 5. The analysis takes into account the type of passenger car drive broken down into selected countries: Czech Republic, Slovakia and Poland.

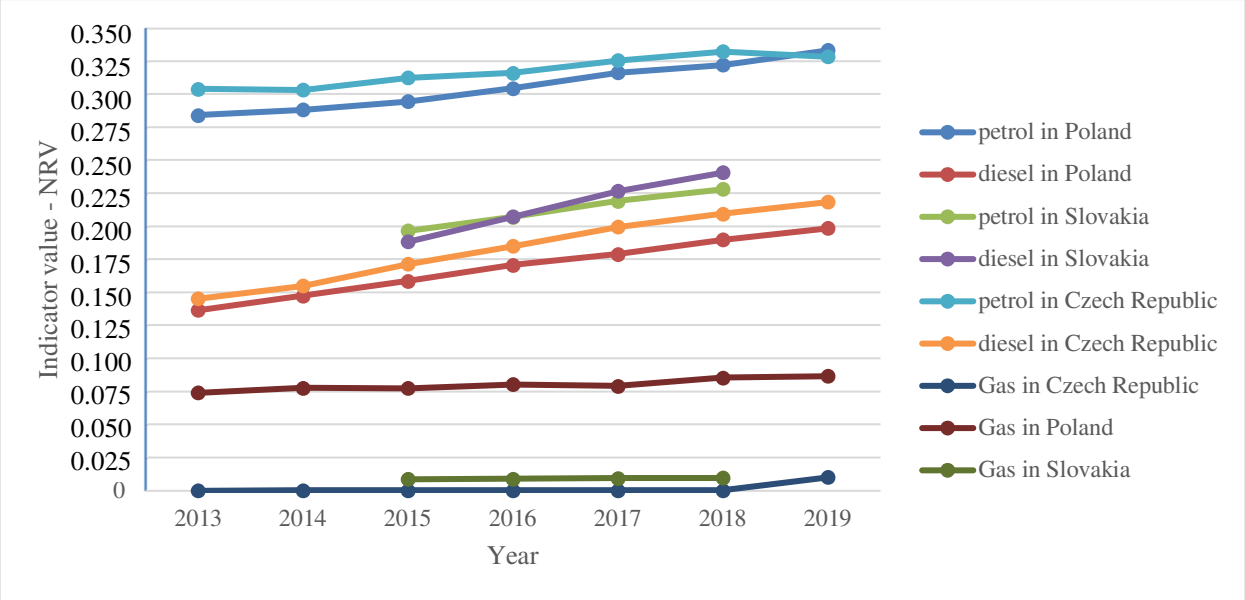

Figure 5 Number of registered vehicles per one resident of the country [15-22]

The conducted analysis of the use of passenger cars, taking into account the means of propulsion and taking into account the population of a given country, shows:

- In Poland, there are 4 times more registered passenger cars than in the Czech Republic and 8 times more than in Slovakia, yet the ratio of vehicles with gasoline and diesel engines for Poland and the Czech Republic is very similar, which means that there are approx. 0.33 of a passenger car that burns gasoline and about 0.2 of a car that burns oil.
- The lowest number of vehicles registered in Slovakia is compared to the other two analyzed countries. In Slovakia, the value of the index of the number of petrol and diesel vehicles is very similar, which distinguishes this country from the others.
- There is the least amount of gas-burning passenger vehicles. The car dealer offers the easiest way is to meet the vehicles on gasoline or diesel, which results in a smaller number of cars with factory-built LPG.
- In Poland, many vehicle owners invest in the installation of gas in the car because of the lower cost of gas compared with petrol or oil.
- Vehicles with a diesel engine are most suitable for driving long distances due to the greater energy efficiency of the fuel, which contributes to lower fuel consumption.
- Gasoline vehicles are generally cheaper than diesel vehicles.
- The popularity of a given type of internal combustion vehicle is not affected by the availability of petrol stations because usually, you can refuel each type of analyzed fuel in one location.

According to a report by the European Automobile Manufacturers Association (fr. Association des Constructeurs Europeens d'Automobiles- ACEA) [16] shows that Polish, Slovak and Czech people drive the oldest cars in Europe. The average age of vehicles in these countries is over 14 years. In the case of Polish drivers, as much as 80% of passenger vehicles are over 10 years old, i.e. at best, these vehicles meet at most the requirements of the EURO4 exhaust gas standard. In the Czech Republic and Slovakia, the situation is slightly better, with the proportion of older vehicles being 64% and 61%, respectively. Older vehicles emit harmful compounds to a large extent, which significantly affect the quality of the air inhaled and the formation of smog. It is because of the smog problem that many European cities are struggling with that the authorities are striving to reduce CO2 emissions and nitrogen oxides from, among others, from the exhaust pipes of Europeans' vehicles. To achieve this, one solution is to encourage the conversion of vehicles from combustion to electric vehicles [16].

The same ACEA report from January 2021 shows that the percentage of electric vehicles, plug-in hybrids and electric hybrids in the entire passenger vehicle fleet in the Czech Republic and Poland are 0.3%, while in Slovakia, about 0.5%, with the European average about 1.2% [16]. The fairly poor results in this group of vehicles are influenced by:

- First, electric and hybrid vehicles are noticeably more expensive than conventionally powered vehicles. In countries where the value of GDP per capita is higher, more interest in this type of vehicle can be noticed.
- Second, the government has little support for private electric vehicle purchases. Only 11 countries in the European Union offer tax benefits both for the purchase and operation of an electric passenger vehicle for private use and for business purposes. In the Czech Republic and Slovakia, the government offers drivers two types of tax relief, while in Poland, there is only an exemption from tax on the purchase of an electric vehicle [16].
- Third, the number of charging stations for electric and electric hybrids is still unsatisfactory. According to a report by the European Court of Auditors, there are 1,020 charging points for electric vehicles in the Czech Republic. For comparison, there are 799 such points in Poland, and 623 in Slovakia [17]. The progress report on the transition to zero-emission mobility prepared by ACEA additionally specifies the number of recharging points per 100 km of road, as shown in Table 5 below.

Table 5 Summary of data on electric vehicles

Country	Total number of vehicles (as of 2019)	Share of electric cars, plug-in cars and electric hybrids in the total rolling stock	Number of charging points	Number of charging points per 100 kilometers of road
Czech Republic	5 989 538	0.3%	1020	0.6
Poland	24 360 166	0.3%	799	0.2
Slovakia	2 391 355	0.5%	623	1.1

Source: own study based on [15-17]

Vehicle charging stations are most often found on Slovak roads. The fact that there are more of them in Poland does not affect accessibility because Poland has a larger territory than Slovakia.

5 Conclusion

Changes and enrichment of society lead to many problems related to the effective management of the city. One of the problems that arises is too many cars and traffic jams in the city. Hence, the idea of city logistics is to

balance private and city transport, as well as encourage residents to use buses, trams, city bikes, etc. The research shows that most cars are driven by only one person, which also seems uneconomical. A passenger car takes up city space even when not in use, as it occupies a parking space. About 7 bicycles can be parked on a parking space for cars with the minimum dimensions required by the regulation, and in the case of a double-decker rack, even 14 bicycles. The city bus does not need any parking spaces in the city centre. It carries out the transport, stopping at a stop, and after a while, it continues its journey.

An electric car has surprisingly the most negative environmental impact when considering the entire life cycle of a vehicle. The battery that powers the entire system contains many hazardous compounds. It is also difficult to talk about completely environmentally friendly electricity transport, which, for example, in Poland, is largely produced from coal, which contributes to climate change and the emission of hazardous substances into the atmosphere. If electricity was obtained exclusively from renewable sources, electric cars would fare better in life cycle analysis. Although the electric car performs unfavourably in its entire life cycle, in the use phase, it fares favourably in terms of exhaust gas emissions and noise in cities. The authorities of the European Union are primarily focused on reducing the pollution load in the city air and thus eliminating smog. In this aspect, the solution turns out to be, e.g. electric cars that are zero-emission, thus in line with the assumptions of the Green Deal.

In Poland, the Czech Republic and Slovakia, there are quite a few electric or hybrid vehicles. This is due to, inter alia, the fact that these vehicles are usually more expensive than traditional internal combustion vehicles. The vast majority of second-hand vehicles are internal combustion vehicles. People do not have adequate knowledge of these vehicles and are afraid to buy them. Most electric or hybrid vehicles are used in richer countries. There are more charging stations in the Czech Republic and Slovakia than in Poland. In Poland, in order to set up a station, it is necessary to contact the Office of Technical Supervision, which extends the time of obtaining a permit, generates additional costs and may ultimately discourage potential future owners of charging stations from establishing such a point. In other European countries, it is not so complicated. In addition, there are 7 times more petrol stations in Poland than there are charging stations. It should also be emphasized that the introduction of exhaust emission standards in Europe has contributed to the necessity of introducing solutions by passenger car manufacturers, which means that the latest combustion cars emit incomparably less harmful substances than vehicles from 15-20 years ago. A solution to lower the average age of vehicles in Poland could be the implementation of more restrictive vehicle registration conditions than just passing the technical inspection. Trends in the development of the economy are aimed at using and motivating society to use electric and hybrid cars. Certainly, a long time will pass until their share will be greater than that of cars running on fuel, diesel or gas. The cost of buying ecological cars is quite high, and the infrastructure (including vehicle charging stations) is not yet fully adapted to the needs. However, this is a good direction of development, although, as the article shows, their negative impact on the environment and society should be reduced.

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DESCRIPTION OF A NOVEL SUPPLIER SELECTION METHOD FOR COMPANIES MANUFACTURING FOOD SUPPLEMENTS

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Keywords: supplier selection, supply chain design, logistics, process development
Abstract: The publication presents a novel supplier selection method that can be of significant help in the optimal design of the supply chains of so-called commissioned food supplement companies. As a prelude to this, the article also explores the literature on existing supplier selection methods using the method of systematic literature search. A key characteristic of the newly developed method is that it incorporates such aspects into the supplier selection process as the environmental impact of logistics processes or the modernity of the supplier's logistics system, both becoming highly important criteria in recent years. The method also supports one and multi actor decision making following state of the art principles in modern data driven supply chain management. As a result, it can be stated that the newly introduced method provides a state of the art approach to supplier selection, while it also takes into account all the traditional aspects related to the field.

1 Introduction

The development and operation of the supply chain of small and medium-sized enterprises producing and selling food supplements has a major impact on competitiveness, as it has a significant impact on the way in which individual customer needs (quality, deadline, cost) are met [1].

In recent decades, customer demand for dietary supplements has increased significantly, further reinforced by the pandemic situation from 2020 [2]. It can be concluded that the dietary supplement product structure is changing extremely rapidly and dynamically [3]. The increasing competitive situation has increased the quality and quantity of the logistics services related to food supplements companies (e.g. shorter lead times, increased flexibility, etc.). It can be said that with the expansion of the product range manufactured and sold by companies, the complexity of manufacturing and logistics processes is constantly increasing, which generates new logistical challenges for today's logistics professionals [4]. The sale of food supplements takes place in a specific case of supply chains, as the products are not the property of the seller as a result of commission sales [5]. In commissioned sales surveys of several companies producing and distributing dietary supplements, it was found that on average 20% of commissioned products were sold in devaluation and 15% were scrapped due to maturity, and there have been many cases where no sales of the products have been made due to a shortage of products in respect of warehouses selling on a 'scheduled' commission [6]. The increasing demand and the complexity of the logistics process, the problems in practice described above, and the possibilities of applying new technological achievements of Industry 4.0 (for example IoT, Big Data, cyberphysical systems, etc.) in the field create new efficiency gains in the field.

Based on the practical experience of the authors, it can be concluded that there are significant shortcomings in the selection of suppliers, the development of processes and their scheduling. This experience served as the primary motivation to develop a novel supplier selection method for the field, based on a practice oriented scientific approach. The development of the method was proceeded by a systematic literature research, in which the existing supplier selection methods were explored. This is covered in section 2 of the publication. Section 3 contains the detailed description of the proposed supplier selection method itself. Finally, section 4 serves as the Conclusion for the publication. Overall, the authors believe that the

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developed novel supplier selection method could be successfully applied to increase the operational efficiency of the examined systems, thereby supporting the competitiveness of the field.

2 Literature research

The literature research was carried out using the Systematic Literature Review (SLR) method. Systematic literature research consists of the following steps:

1. Identifying research questions (Who's done what so far? Who did or published the research first? Where are the scientific gaps?).
2. Mapping related literature, primarily through online databases.
3. Reducing results, selecting relevant literature and reading them to determine the main direction of research (definition of extra keywords, based on authors, by date, etc.).
4. Develop a method of processing and analyzing literature.
5. Formulation of major scientific breakthroughs and results.
6. Definition of scientific gap or bottleneck.

On this basis, the first step is to define keywords that cover the topic of research work [7].

Table 1 Keyword hits in Scopus, Web of Science and ScienceDirect [Source: Own Edit]

	Scopus						Web of Science						ScienceDirect					
search keywords	supplier selection	supplier selection AND medicine/pharma	supplier selection AND medicine/pharma AND method	supplier selection AND method	supplier selection AND weight	supplier selection AND method AND weight	supplier selection	supplier selection AND medicine/pharma	supplier selection AND medicine/pharma AND method	supplier selection AND method	supplier selection AND weight	supplier selection AND method AND weight	supplier selection	supplier selection AND medicine/pharma	supplier selection AND medicine/pharma AND method	supplier selection AND method	supplier selection AND weight	supplier selection AND method AND weight
search range	title, abstract, keywords	title, abstract, keywords	title, abstract, keywords	title, abstract, keywords	title, abstract, keywords	title, abstract, keywords	title, abstract, keywords	title, abstract, keywords	title, abstract, keywords	title, abstract, keywords	title, abstract, keywords	title, abstract, keywords	title, abstract, keywords	title, abstract, keywords	title, abstract, keywords	title, abstract, keywords	title, abstract, keywords	title, abstract, keywords
2000-2020 in total	7550	50	24	3086	1811	725	4616	22	11	2140	1086	831	1282	3	0	510	186	134
2000	88	0	0	21	5	3	30	0	0	6	3	1	13	0	0	2	1	0
2001	93	2	0	20	0	0	35	0	0	6	0	0	14	0	0	4	0	0
2002	75	0	0	14	2	0	25	0	0	6	3	1	8	0	0	2	0	0
2003	138	0	0	26	5	2	43	0	0	9	0	0	20	0	0	3	1	1
2004	142	2	0	29	4	0	42	1	0	7	5	3	17	0	0	2	0	0
2005	198	1	0	49	10	5	62	1	0	15	2	1	18	0	0	5	2	1
2006	240	3	1	62	8	4	60	0	0	18	4	2	24	0	0	7	4	3
2007	261	7	0	87	24	16	76	0	0	15	4	3	34	0	0	9	2	1
2008	343	1	1	142	35	25	113	0	0	41	12	8	35	0	0	11	2	1
2009	378	1	0	137	51	34	160	0	0	54	20	10	70	0	0	21	6	4
2010	407	1	1	137	48	28	157	1	1	52	26	16	55	0	0	15	5	2
2011	453	0	0	174	58	40	189	0	0	74	41	25	80	0	0	35	15	10
2012	401	2	1	166	57	40	183	0	0	59	29	18	80	0	0	33	14	9
2013	445	2	2	184	65	46	205	1	1	88	44	29	86	0	0	37	14	11
2014	500	2	1	227	72	58	259	1	0	127	59	46	93	0	0	36	11	7
2015	459	5	3	176	72	41	350	2	2	138	77	46	102	0	0	46	21	13
2016	484	4	1	215	58	45	374	3	0	185	89	65	81	1	0	33	9	7
2017	510	3	1	227	875	57	412	2	1	204	98	76	100	1	0	43	19	18
2018	596	3	2	286	100	71	511	4	2	281	144	115	113	0	0	53	19	11
2019	663	7	7	357	123	101	665	3	2	363	200	174	131	0	0	66	20	18
2020	676	4	3	350	139	109	665	3	2	392	226	192	108	1	0	47	21	17

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In general, the process of supplier selection is based on several aspects of decision making. The decision-making process is complicated by the need to take into account the characteristics of the material to be scored, the participants in decision making and its role in the organization when analysing the criteria [8]. The literature on supplier selection is extremely rich, many publications analyse different aspects of decision-making methods. The literature analysis focuses on the examination of decision making methods and the analysis of the criteria used

As shown in Figure 1, systematic literary research was carried out first in the chapter using the following keywords when analysing the literature in the field:

- selection supplier / supplier selection,
- medicine or pharma / medicine,
- method / method,
- weight / weight

In the databases, a simple search was also used for this literary research section, where only two search words were given first, then several search words, the combinations and results of which are given in Figure 1.

The table shows that searches for original keywords have been narrowed down to "supplier selection AND method AND weight" to create a more limited search result. After that, the search results for each keyword resulted in sufficiently relevant results, so a total of 1690 works were selected and analysed in detail. It can be said that the words medicine/pharma have greatly reduced the result of the hit.

The chronological distribution of the selected publications is illustrated in Figure 2, where it can be observed that the number of publications with an increasing trend towards the research directions examined is displayed year after year.

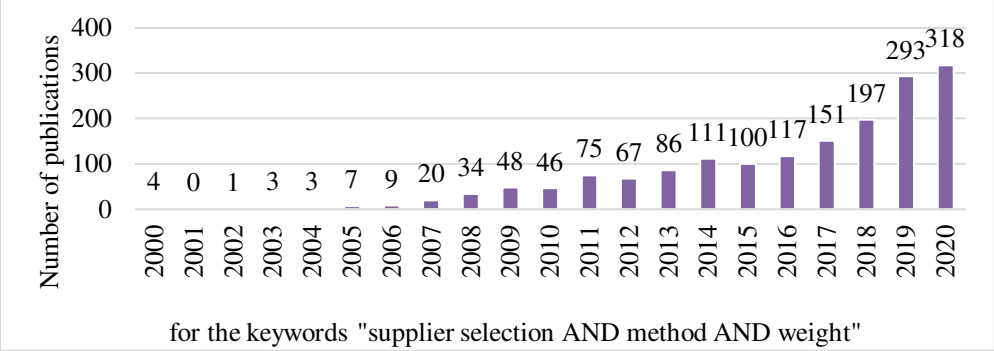

Figure 1 Number of publications related to the topic by year of publication [Source: Own Edit]

Figure 3 illustrates the importance of different disciplines in the publication list of the Scopus scientific database based on data from the past 20 years. It can be observed that the delimited field of research clearly shows a multidisciplinary character. Research related to engineering also plays a prominent role here, but there are also publications approaching pharmaceuticals and social aspects. Figure 7 shows that there are few publications on this subject in the pharmaceutical sector.

Figure 4 is based on data from the Scopus database for the last 5 years, which is based on the search for the keywords "supplier selection AND method AND weight", which together contains 424 publications. The search results then searched the search results for keywords that appear in scientific works outside of the keywords you specify. It can be observed that decision support and supply chains play a major role in the majority of publications related to the subject area.

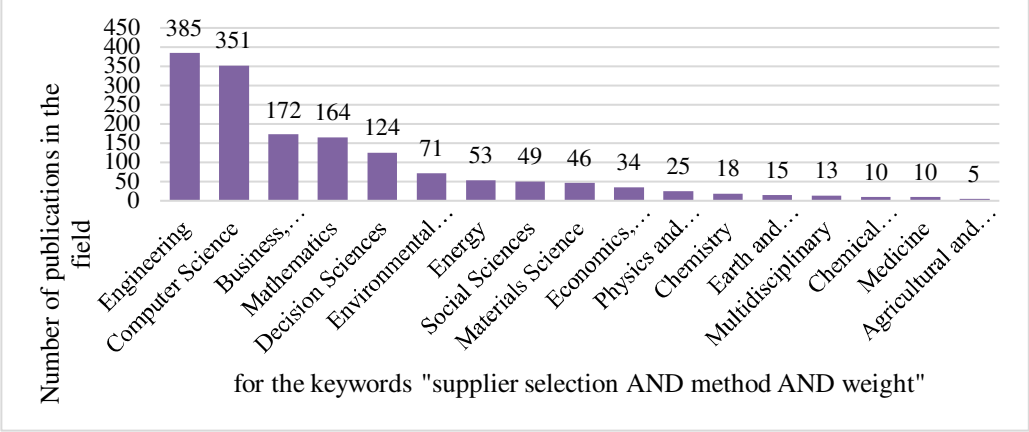

Figure 2 The emergence of disciplines in publications [Source: Own Edit]

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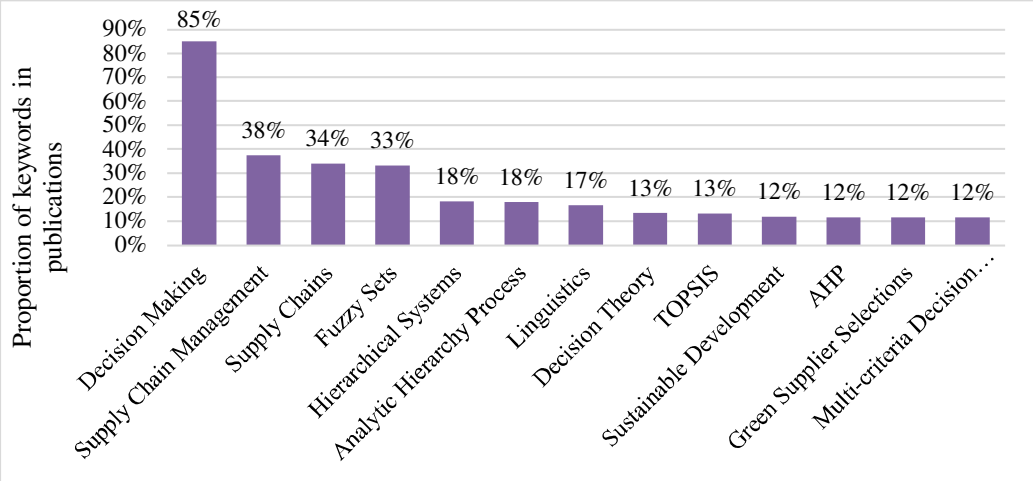

Figure 3 Distribution of keywords other than search keywords in publications [Source: Own Edit]

As a further analysis, the 10 most published persons on the subject were selected (Table 1). It can be said that the total number of authors involved in the publication of four or more articles is estimated at 39.

Table 2 The authors who published 10 most published authors for "supplier selection AND method AND weight" in the Scopus scientific library between 2015 and 2020 [Source: Self-edit]

Author	published articles	Author	published articles
Wei, G.	15	Wu, J.	9
Liao, H.	11	Zavadskas, E.K.	9
Kar, S.	10	Wei, C.	8
Krishankumar, R.	9	Wan, S.P.	8
Ravichandran, K.S.	9	Chen, T.Y.	7

The following summary literary review was prepared, focusing on outstanding authors and most cited publications, by processing 1690 works (Scopus, Wos, ScienceDirect in total) delimited in systematic literature research.

Jenoui and Abouavdellah published about supplier selection for pharmaceutical products in 2015. They note that one of the most important logistical challenges in this sector is the choice of supplier, but there are few methods for decision-makers to choose the optimal supplier. A new heuristic model will be created that takes into account only costs and deadlines [9].

Voeng and Kritchanchai will use VMI technology to supply medicines between distributors and hospitals in 2019. In the study, a multi-aspect decision-making method based on the AHP method is used to determine weight factors for the selection of suppliers, illustrating the critical factors of the use of VMI in different types of hospitals [10].

In a case study in 2019, Bakhtiar et al. also analyzed the selection of a hospital supplier for pharmaceuticals. Supplier selection is treated by one of the methods of the MCDM "Multi Criteria Decision Making" model, which takes into account several criteria, the "gray-based major set method", which involves several decision-makers who play an important role in the hospital [11].

Pourghahreman and Rajabzadeh discussed the selection of pharmaceutical supplier agents in 2015, listing the criteria that have been defined from various publications, thus selecting 10 qualitative and 10 quantitative criteria from 38 factors. From these supplier assessments, a ranking is established using the TOPSIS and PROMETHEE methods. According to the results of the survey, quality criteria are one of the most important factors in the choice of supplier [12].

In 2006, Chen and his co-authors published a paper on fuzzy-based decision-making to address the problem of supply chain supplier selection. In their research, they propose an MCDM model for supplier selection. According to the TOPSIS method, a proximity co-efficient is determined to determine the ranking order of all suppliers [13].

Hossein and his team discussed supplier selection in 2011. In their publication, they describe that the process of purchasing raw materials is influenced by a number of parameters. The most important of these parameters are the product arrival time (order lead time), purchase and delivery costs and raw material quality from the date of order [14].

In 2017, Gupta and Barua discussed the selection of suppliers for SMEs based on their green innovation capacity. The aim of their study is to examine supplier selection among SMEs on the basis of their green innovation capacity. A three-phase methodology is used, the first phase of which is the green innovation criterion, the second phase is the ranking of selection criteria, and the third phase uses the TOPSIS method to prioritize suppliers

based on the weight of the criteria obtained in the second phase [15].

Sarkis and Dhavale conducted a supplier selection in 2015 with sustainable operations in mind. In the sustainable approach, a three-prone set of criteria is set up and a new methodological approach based on the Bayes framework and the Monte Carlo Markov Chain (MCMC) simulation will be developed using specific selection targets for supplier ranking and selection [16].

In the supply chain, it can be seen that in the last five years, environmental protection and the development of new methods have become one of the important aspects of supplier selection. A number of new methods have been developed or further developed on the basis of their own criteria, which can take into account several aspects [15-20].

Based on the literature analysis, it can be concluded that there are a huge number of supplier selection methods in a wide variety of areas, but there is little literature on medicinal products or dietary supplements. There is no elaborated method in the referred literature to provide a general solution for selecting suppliers for all companies producing dietary supplements. Some of the methods do not take into account quality parameters (e.g., concentration, proportion of transport errors, etc.), while others do not consider environmental aspects, the importance of which is increasingly appreciated nowadays.

3 Development of a supplier selection method for companies producing dietary supplements that sell commissioned

A significant part of supplier selection methods focusses on the automotive industry [21-23], but a number of methods have also been developed for food supplements and pharmaceutical companies [24-27]. It can be concluded that some of these selection methods focus strictly on costs, other methods focus on quality or environmental protection, but the approach that takes into account logistical aspects has not been elaborated in detail so far. One of the literatures with the most diverse criteria [27], which produces a summary analysis of several publications in the field of supplier selection [28-40], also does not take sufficient account of logistical aspects.

With regard to companies producing food supplements, this aspect is particularly important as delayed deliveries, long delivery lead times or insufficiently defined logistical costs can significantly impair the competitiveness of companies.

As a result of the foregoing, the objective was to develop a general supplier selection method for companies producing commissioned dietary supplements that are suitable for taking into account relevant aspects as well as for single and multi-stakeholder decision-making. The chapter also describes the process of supplier selection, the criteria to be examined and the method of deciding on supplier selection.

3.1 Supplier selection process

The task of selecting a supplier is to provide the company with raw materials according to the need and cost saving in the range, quantity, quality, and time required by the company's operations or production program [37]. The following is the process of selecting a supplier based on practical experience and analysis of the literature [41-42].

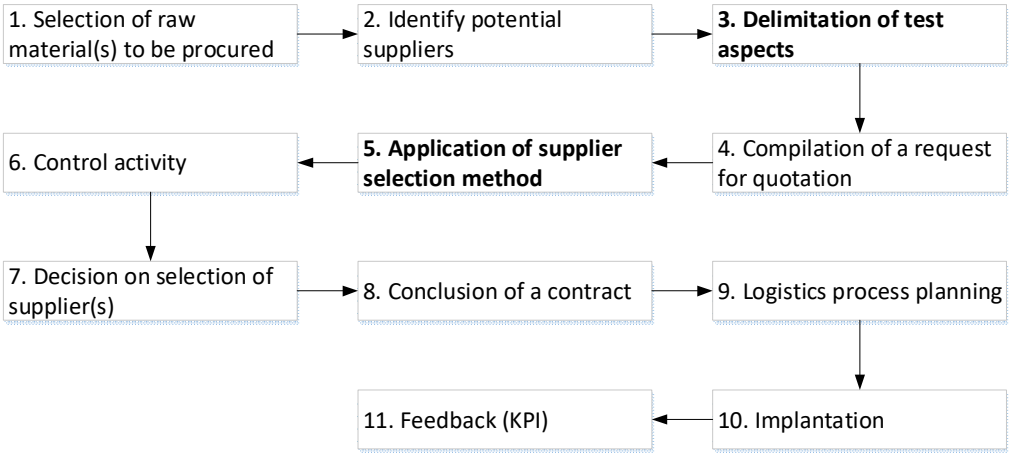

Figure 4 Supplier selection process [Source: Own Edit]

Process steps (Figure 5):

Step 1. The inventory policy of the central manufacturer and the commissioning company determines the range of raw materials to be procured.

Step 2. Based on the raw materials to be procured, the suppliers involved in the study will be selected. Relevant sources of information collection:

- corporate relationship system (former suppliers, etc.),

- information from a consulting firm,
- internet search.

Step 3. Central manufacturing and commissioning companies determine the test criteria that are important to them based on the raw material(s) to be procured.

Step 4. When compiling a request for proposals, particular attention should be paid to the objective and easy evaluation of tenders relating to the selected test criteria.

Step 5. Suppliers that are the best alternative based on the test criteria set out in Step 3 will be selected using the supplier selection method.

Step 6. Control activities should ensure the establishment of controls to reduce risks to the achievement of organizational objectives, including the soundness of the offer from selected suppliers. The control activity should also cover the economical, efficiency and efficiency adequacy of suppliers.

Step 7. Following the steps described in the previous steps, optimal suppliers will be selected.

Step 8. The selected supplier is contacted by the central logistics and production company, and the supplier contract is concluded on the basis of the above given quotation. In relation to the service contract, it is necessary to clearly define the powers, the possibilities for sanctioning and premeditation, and the indicators attached to them.

Step 9. After the conclusion of the contract, the procurement logistics process (activities, tools used, scheduling, etc.) must be planned.

Step 10. The implementation and testing of the specified purchasing system will be carried out.

Step 11. In order to enforce the sanctions and premeditation options set out in the service contract, the indicators of the operating system will be monitored.

3.2 *Definition of the test criteria*

Supplier selection criteria can take into account qualitative and quantitative aspects, which can be interpreted as a minimizing or maximizing objective function component. The logistic indicators described up to (1) ... (5) describe the quantitative aspects to be taken into account, and the logistic indicators described up to (6)… (8) describe the definition of the values of the qualitative aspects. These relevant indicators are defined below.

3.2.1 Order lead time

The lead time can be interpreted between two arbitrary points in the logistics chain. One of the basic principles of its calculation when purchasing is that parallel events should be considered the longest. The expected lead time (average time) and its standard deviation are taken into account.

When calculating the order lead time, we calculate the general case that the raw materials, regardless of whether they are supplied directly or indirectly, are ordered at the previous stage, i.e., the distribution warehouse of an indirect supplier, and from there the raw material demand can be directly met. The order lead time can be calculated in the same way for direct and indirect supply [41].

In the case of raw material r, v. the supplier may be given the order lead time (1) on the basis of the relationship:

$$t^{B}_{r,v} = t^{BE}_{r,v} + t^{BCS}_{r,v} + t^{BS}_{r,v} + t^{BW}_{r,v}, [\text{hour}] \qquad (1)$$

where:

- $t^{B}_{r,v}$: the total order lead time for r. raw material at the v. supplier,
- $t^{BE}_{r,v}$: the preparation time after ordering at the v. supplier in the case of r. raw material (purchase and manufacture of components for raw materials),
- $t^{BCS}_{r,v}$: post-order packing time and ERKE training time at the v. supplier in the case of r. raw material,
- $t^{BS}_{r,v}$: delivery time after order in the case of r. raw material at the v. supplier,
- $t^{BW}_{r,v}$: waiting time (storage) time after ordering at the v. supplier in the case of r. raw material.

The main factors influencing the order lead time in the case of dietary supplemental raw materials, the supplier's distance from the central production plant, the flexibility of the supplier's production equipment, production programming, the mode of transport, the characteristics of the means of transport, the purchase of raw materials, the flexibility of the purchase of packaging material, the possibility of delivery from stock, the size of the available stocks and the customs procedure time.

The values determined on the basis of the (1) shall be recorded in matrix form:

$$\mathrm{T^B} = \left[\mathrm{t^B_{r,v}}\right], [\text{hour}] \qquad (2)$$

where the matrix contains the total order lead time for the v. supplier for r. raw material

3.2.2 Total acquisition cost

The purchase price of the raw material for the dietary supplements to be sold significantly affects the available margin weight. It directly affects expenditure since the purchase value of goods sold is a significant cost factor for commercial enterprises. However, it also affects turnover indirectly, as the purchase price affects the sales price, including the quantity that can be sold. The components of the actual purchase price for a product are the price invoiced by the vendor, the separate cost of the purchase, and the preferences or preferences associated with the purchase of the product.

The price at which companies producing food supplements that sell them commissioned manages to obtain their raw materials from their supplier partners depends on several factors. The validated purchase price of the product is influenced by its quality and earned value,

the long term business relationship, the quantity of the goods purchased, and the use of ancillary services related to the purchase. However, behind this apparent diversity lies essentially two factors affecting the invoiced price established by the supplier. These are the inputs related to the production and distribution of the product and the market position of the product. In addition to the invoiced price less discounts plus surcharges, all expenses are included in the purchase price, which are individually linked to the raw material until it is delivered to the warehouse. These factors include freight costs, loading fees, product purchase costs, and customs clearance fees.

For r. raw material, the cost of the total purchase at the "v." supplier can be determined as follow:

$$k_{r,v}^{B} = k_{r,v}^{BF} + k_{r,v}^{BR} + k_{r,v}^{BB} + k_{r,v}^{BV}, [\text{EUR}] \quad (3)$$

where:

- $k_{r,v}^{B}$: the total cost of purchase for r. raw material at the v. supplier,
- $k_{r,v}^{BF}$: total freight costs up to arrival at the v. supplier in the case of r. raw material,
- $k_{r,v}^{BR}$: all loading costs up to arrival at the v. delivery point in the case of r. raw material,
- $k_{r,v}^{BB}$: the cost of purchase in the case of r. raw material at the v. supplier,
- $k_{r,v}^{BV}$: customs clearance costs for r. raw material at the v. supplier.

Based on (3), the previous ones can be given in matrix form:

$$K^{B} = \left[k_{r,v}^{B}\right], [\text{EUR}] \quad (4)$$
$$(r = 1,2 \dots n), \quad (v = 1,2 \dots m)$$

where the matrix contains the total acquisition cost for the "v." supplier for r. raw material.

3.2.3 Raw material quality

One of the most important factors in the creation of the product is the quality of the purchased raw material. By increasing the quality of the ordered raw material, the concentration of the active substance in it, the purchase price increases, and the production time of the ordered raw material increase, but the quantity of raw material ordered decreases, since the quantity of active ingredient prescribed in the formula can be satisfied with fewer raw materials. It can be said that the quality of the raw material can be related to the cost of purchasing the ordered raw material and its order lead time. This is not typical, but there may be cases where a raw material contains several components, in which case it is necessary to prepare and manage several quality matrices. The developed method is presented on a basic ingredient, which can be easily extended to several components.

On this basis, the matrix N^{B} can be determined, which for each supplier contains the value of the raw material concentration for each product purchased:

$$N^{B} = \left[n_{r,v}^{B}\right], [\%] \quad (5)$$
$$(r = 1,2 \dots n), \quad (v = 1,2 \dots m).$$

3.2.4 Environmental impact of logistics process

The environment, which is becoming increasingly important in all areas of social and economic life today, also has high expectations of logistics. It has a significant impact, for example, on procurement, the use of environmentally friendly recyclable materials, the use of so-called 'green' technologies, the collection and handling of hazardous substances and the environmental impact values of vehicles for transport [43].

An increasingly important aspect of the development of supply chains is to reduce emissions in the logistical process of deliveries. To take this into account, the environmental load matrix (6) of logistics processes is defined, where the subjective, individual competence of the company is entrusted to evaluate each supplier on a scale of 1 to 10 (1=worst, 10=best).

$$E^{B} = \left[e_{r,v}^{B}\right], [\text{point}] \quad (6)$$

3.2.5 Modernity of the supplier's logistics system

A key issue in the selection process may be the modernity of the logistics system of suppliers. This aspect affects both the cost and quality of the procurement process. To take this into account, a matrix (7) determining the modernity of the supplier's logistics system is defined, where the company subjectively evaluates suppliers on a scale of 1 to 10 (1=worst, 10=best).

$$P^{B} = \left[p_{r,v}^{B}\right], [\text{point}] \quad (7)$$
$$(r = 1,2 \dots n), \quad (v = 1,2 \dots m).$$

3.2.6 Reliability

On the basis of financial and supplier reference data, account should be taken of the reliability of a particular supplier, as the supply of raw materials may result in risks if an unstable supplier is selected. The reliability matrix (8) is defined to validate this aspect, where the company scores its suppliers between 1.10 as described in the previous criterion (1=worst, 10=best).

$$M^{B} = \left[m_{r,v}^{B}\right], [\text{point}] \quad (8)$$
$$(r = 1,2 \dots n), \quad (v = 1,2 \dots m).$$

3.3 *Description of the supplier selection decision method*

With regard to the supplier selection method, a multi-faceted decision-making method has been developed, the important element of which is the definition and

normalization of the limitation of the selected logistical indicators and the application of the Churchman-Ackoff weighting method.

Steps to apply the method:

Step 1: Define logistical indicators to be minimized and maximized, grouped as follows.

Components to minimize:
- total costs related to delivery,
- total lead time of purchase,
- environmental impact of the logistics process,

Components to maximize:
- quality of raw material,
- the modernity of the supplier's logistics system,
- supplier's reliability.

Step 2: Define supplier selection criteria. In this step, the criteria for supplier selection are defined in paragraph 1. (8) by specifying restrictive conditions for relationships.

Total lead time: In order to meet customer needs in a timely manner, it is important to set the maximum expected lead time:

$$t_r^B \leq t_{r,max}^B \tag{9}$$

Total cost of procurement: In order to ensure the competitiveness of the company, it is important to fix the maximum possible acquisition cost for the selection of suppliers:

$$k_r^B \leq k_{r,max}^B \tag{10}$$

Environmental impact of the logistics process: Using the "green" technologies used by the supplier, it is important to record the maximum environmental load on the basis of the collection and handling of hazardous substances and the environmental load values of the vehicles during transport:

$$e_r^B \leq e_{r,max}^B \tag{11}$$

Raw material quality: In order to comply with the formula prescribed for the production, a minimum or upper raw material concentration may be set in order to comply with the formula prescribed for the supply of raw materials:

$$n_{r,min}^B \leq n_r^B \leq n_{r,max}^B \tag{12}$$

In terms of the modernity and reliability of the supply supplier's logistics system, lower limits may be laid down, for which there is a:

$$p_{r,min}^B \leq p_r^B \tag{13}$$
$$m_{r,min}^B \leq m_r^B \tag{14}$$

Step 3: Define reduced matrices. In this step, the values of matrix (1) to (8) are modified based on the conditionality described in Step 2. Formally, this means that all reduced matrices are marked with one override.

Step 4: Normalize logistical indicators. In this respect, the value of each target function component is transformed from 0 to 1. It can be seen that there are two types of target function components in the optimization task, there are three minimization functions (15), (18), (25) and three maximizing target functions (21), (28), (32). They should be managed together during optimization. Co-treatment requires that all target functions be either maximized or minimized. In the developed method, the minimizing target function components have been left unchanged, the maximizing target functions have been converted into minimizing target function components.

Normalization of logistical indicators:

Normalization of purchase cost matrix values: The relationship (15) is given for r. raw material in terms of the optimal v. supplier for all transport costs. Then, for all values, formula (16) can be used to determine the normalized target function components.

$$K_r^{B\prime} = \min_{\mathrm{v}}\{k_{r,\mathrm{v}}^{B\prime}\};\ (v = 1,2,\dots,m;\ r = 1,2,\dots,n) \tag{15}$$
$$(r \text{ belongs to a } \mathrm{v}_{opt})$$
$$\gamma_{r,\mathrm{v}}^1 = \frac{K_r^{B\prime}}{k_{r,\mathrm{v}}^{B\prime}};\ (v = 1,2,\dots,m;\ r = 1,2,\dots,n) \tag{16}$$
$$0 < \gamma_{r,\mathrm{v}}^1 \leq 1 \tag{17}$$

Normalization of the procurement lead time matrix: Based on the relationship (18), the optimal v. supplier for r. raw material is the total lead time related to the supply. The normalized target function components can then be determined using formula (19) for all values:

$$T_r^{B\prime} = \min_{\mathrm{v}}\{t_{r,\mathrm{v}}^{B\prime}\};\ (v = 1,2,\dots,m;\ r = 1,2,\dots,n) \tag{18}$$
$$(r \text{ belongs to a } \mathrm{v}_{opt})$$
$$\gamma_{r,\mathrm{v}}^2 = \frac{T_r^{B\prime}}{t_{r,\mathrm{v}}^{B\prime}};\ (v = 1,2,\dots,m;\ r = 1,2,\dots,n) \tag{19}$$
$$0 < \gamma_{r,\mathrm{v}}^2 \leq 1 \tag{20}$$

Normalization of quality matrix values: Based on the relationship (21), the optimal v. supplier for r. raw material is the quality (concentration) of the raw material related to the supply. Quality components are normalized using the relationship (22).

$$N_r^{B\prime} = \max_{\mathrm{v}}\{n_{r,\mathrm{v}}^{B\prime}\};\ (v = 1,2,\dots,m;\ r = 1,2,\dots,n) \tag{21}$$
$$(r \text{ belongs to a } \mathrm{v}_{opt})$$
$$\gamma_{r,\mathrm{v}}^3 = 1 - \frac{n_{r,v}^{B\prime}}{N_r^{B\prime}};\ (v = 1,2,\dots,m;\ r = 1,2,\dots,n) \tag{22}$$
$$0 < \gamma_{r,\mathrm{v}}^3 \leq 1 \tag{23}$$

Normalization of the environmental load of the procurement logistics process: Based on the relationship (24), the optimal v. supplier for r. raw material is the environmental burden of the supply related procurement logistics process. Quality components are normalized using the relationship (25):

$$E_r^{B\prime} = \min_{\mathrm{v}}\{e_{r,\mathrm{v}}^{B\prime}\};\ (v = 1,2,\dots,m;\ r = 1,2,\dots,n) \quad (24)$$

(r belongs to a v_{opt})

$$\gamma_{r,\mathrm{v}}^{4} = \frac{E_r^{B\prime}}{e_{r,v\prime}^{\mathrm{B}}};\ (v = 1,2,\dots,m;\ r = 1,2,\dots,n) \quad (25)$$

$$0 < \gamma_{r,\mathrm{v}}^{4} \le 1 \quad (26)$$

Normalization of the logistics system of suppliers: Based on the relationship (27), the optimal v. supplier for r. raw material is the modernity of the supplier logistics system related to the supply. Quality components are normalized using the relationship (28):

$$P_r^{B\prime} = \max_{\mathrm{v}}\{p_{r,\mathrm{v}}^{B\prime}\};\ (v = 1,2,\dots,m;\ r = 1,2,\dots,n) \quad (27)$$

(r belongs to a v_{opt})

$$\gamma_{r,\mathrm{v}}^{5} = 1 - \frac{p_{r,v\prime}^{B}}{P_{\mathrm{v}}^{\mathrm{B}\prime}};\ (v = 1,2,\dots,m;\ r = 1,2,\dots,n) \quad (28)$$

$$0 < \gamma_{r,\mathrm{v}}^{5} \le 1 \quad (29)$$

Normalisation of supplier reliability: Based on the relationship (30), the optimal v. supplier for r. raw material is the supplier's reliability in relation to supply. Then, for all values, formula (31) can be used to determine the normalized target function components:

$$M_r^{B\prime} = \max_{\mathrm{v}}\{m_{r,\mathrm{v}}^{B\prime}\};\ (v = 1,2,\dots,m;\ r = 1,2,\dots,n) \quad (30)$$

(r belongs to a v_{opt})

$$\gamma_{r,\mathrm{v}}^{6} = 1 - \frac{M_r^{B\prime}}{m_{r,v\prime}^{\mathrm{B}}};\ (v = 1,2,\dots,m;\ r = 1,2,\dots,n) \quad (31)$$

$$0 < \gamma_{r,\mathrm{v}}^{6} \le 1 \quad (32)$$

Step 5: Weighting normalized target function components. As the importance of target functions is generally different, target function values should be weighted according to their importance [44]. The weighting factors for the target functions are set to η_1; η_2; η_3; η_4; η_5; η_6 which the Churchman-Ackoff weighting method was used to determine. The method basically relies on the values of a single professional person but can be easily extended to the assessment of several persons if necessary [45].

Steps of Churchman-Ackoff's weighting method [46]:

Step 1. Sorting logistics indicators according to their importance (C_1 most important, then $C_2, \dots, C_6$).

Step 2. The weight of aspect C_1 is taken as 1, and then the weight of the other aspects relative to C_1 must be given ($W_1, W_2, \dots, W_6$). In order to increase the reliability of the estimate, each aspect should be compared with groups that can be formed from all aspects. For example C_1 $with\ \{C_2, \dots, C_6\}, \{C_2, \dots, C_{n-1}\}, \dots, \{C_2, \dots, C_3\}$. If C_1 is more important, but the inequality given by the initial weights does not prove this, the value of W_1 must be adjusted so that the inequality is satisfied (if less, if equal is the same principle.

Step 3. Compare C_2 with $\{C_3, C_4, \dots, C_6\}$ as in step 2.

Step 4. Continue the comparisons until a comparison of C_{6-2} and $\{C_{6-1}, C_p\}$ is obtained.

Step 5. Divide the weight of each aspect by $\sum_{l=1}^{p} W_l$, thereby gaining the weights described in the relationship (33), the sum of which will be 1.

Factors $\eta_1 - \eta_6$ are subject to the relationships (33):

$$\begin{array}{lll} 0 < \eta_1 \le 1, & 0 < \eta_2 \le 1, & 0 \le \eta_3 < 1 \\ 0 < \eta_4 \le 1, & 0 < \eta_5 \le 1, & 0 \le \eta_6 < 1 \end{array} \quad (33)$$

$$\sum_{i=1}^{6} \eta_i = 1$$

Step 6: Define a target function. Weighted target function values are defined as follows:

$$E_{r,\mathrm{v}} = \gamma_{r,\mathrm{v}}^{1} \cdot \eta_1 + \gamma_{r,\mathrm{v}}^{2} \cdot \eta_2 + \gamma_{r,\mathrm{v}}^{3} \cdot \eta_3 + \gamma_{r,\mathrm{v}}^{4} \cdot \eta_4 + \gamma_{r,\mathrm{v}}^{5} \cdot \eta_5 + \gamma_{r,\mathrm{v}}^{6} \cdot \eta_6 \quad (34)$$

where the matrix $E_{r,\mathrm{v}}$ contains the weighted target function values by r. raw material and v. supplier.

The optimal supplier for r. raw material can be defined as follows:

$$U_r = \min_{\mathrm{v}}\{E_{r,\mathrm{v}}\} \quad (35)$$

$(r = 1,2 \dots n)$

where U_r the minimum value of the target function for r. raw material to which the proposed supplier (v_{opt}).

4 Conclusions

The publication presented a novel supplier selection method for companies producing commissioned dietary supplements, which could enable the supply chains of those companies to be developed more efficiently. Furthermore, prior to this, the literature on existing supplier selection methods was explored using the method of systematic literature research.

The results described can be used for the practice primarily for companies engaged in the placement of commission and commission stocks. A test method can be presented for a specific example, and with minimal correction it can be applied to all supply chain types.

However, in order to properly explore all possible application cases, a rigorous testing phase would be further required, during which all the possible combinations of the utilized parameters could be examined and a detailed sensitivity analysis could be implemented. This would be especially important in relation to the environmental impact, the modernity and the reliability indicators, which are used to quantify complex and qualitative aspects of the supplier selection criteria. Similarly, it would be also useful for validating the determined weights of the indicators in a given application. Therefore, the next forthcoming step in the research will be the realization of such a testing program, which can significantly contribute to the wider scale applicability of the developed method.

A main objective of the research was also to explore and implement the longer term possibilities for further development of the introduced test method. A number of further development options can be described, among which the extension of the test model to the operation of commissioned sales companies with several central warehouses and production plants, as well as the development of a computerized web application for the application of test methods at the enterprise level. By implementing these further development ideas, it may be possible to create a decision support tool that can be used in a way that can be used extensively and easily by any commission sales company during the supplier selection process.

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