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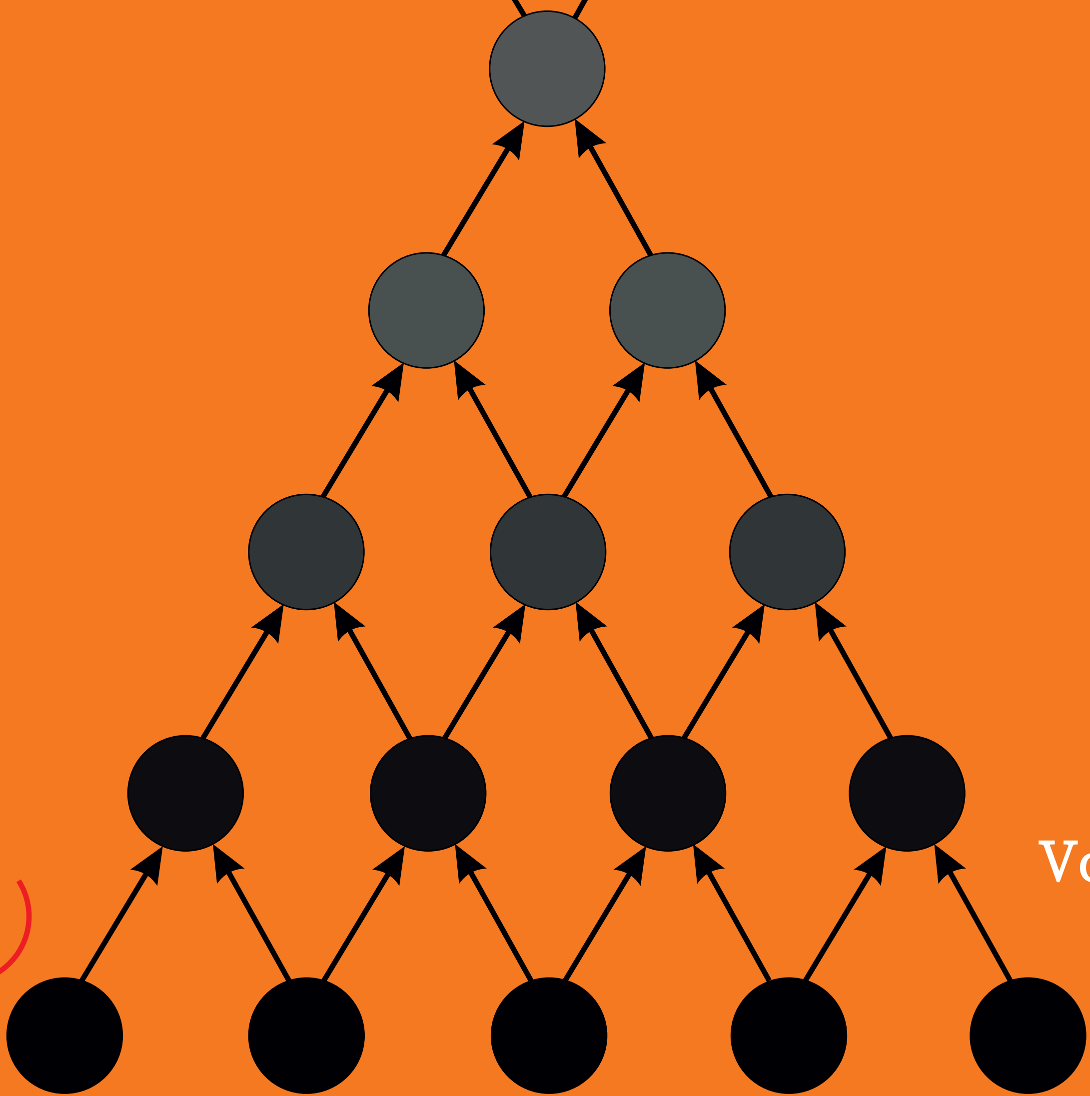

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TRANSFORMATION THE LOGISTICS TO DIGITAL LOGISTICS: THEORETICAL APPROACH

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Abstract: In connection with Industry 4.0, professional publications are mostly focused on the introduction of new technologies, research of new and intelligent materials, etc. which mean evolution compared to the present. However, it is also necessary to focus on the implementation of the product within the supplier-customer relationship, as the customer's impact on the final product is significant. The article deals with the transformation of the Supply Chain using the DDMRP methodology, which aims to maintain best practices, address their shortcomings, and integrate pull-based replenishment tactics. It is a comprehensive tool that integrates the entire Supply Chain, including the integration of customers and suppliers.

1 Introduction

Since manufacturing companies, trading companies, transport companies, etc. are dependent on the timely provision of input materials, implementation of handling and transport activities in the production and distribution of products, provision of activities in warehouses, logistics is the key factor, which has the appropriate methods, techniques, and tools to effectively manage these activities. The integrated logistics system in the company should be based on the business strategy and ensure a shortening of innovation cycles, global supplier-business-customer interconnection, customization of products, and logistics services using integrated information and communication technologies. Logistics can, therefore, be understood as customer-oriented planning and management of business value chains through information technology support. Decentralization of management and autonomy of individual company structures that are synergically synchronized became the basis for the application of cyber-physical systems/CPS into production, creation of information and communication networks between objects and systems, implementation of systems for collection, analysis, and evaluation of large data volumes and virtual creation space for the contact between internal and external environment [1-4].

These are new approaches in the organization and management of production. Instead of conventional pressure control systems of production control, each product (intelligent element) will control itself, i.e. selects the processing sequence and determines the machine, resp. equipment for the operation in time will provide the means for its processing and handling (tools, transport elements, etc.). Production facilities and logistics elements will also be regulated separately and linked to the product through highly efficient information and communication systems. Interconnection of technologies with production processes through communication technologies and the introduction of so-called methods Self –X properties (self-regulation, self-configuration, self-diagnostics, self-optimization, self-protection) allow for autonomous resp. partially autonomous activities of machines and equipment, resp. logistics elements, which increases flexibility and efficiency. It opens up the ability to process large amounts of data in real-time, without interfering with real systems and processes to create a virtual environment, using digital technology and implementing digital models to create a digital environment, creating a new environment for the development of Industry 4.0. Communication and collaboration of people, intelligent machines, devices, logistics, and products is the main purpose of Industry 4.0 [5-8].

1.1 Characteristics of Logistics 4.0

In Industry 4.0, products, manufacturing systems, warehouses are connected to global production networks. In this way, it is possible to communicate with each other, to move available data, to trigger processes, while still leaving these entities room for autonomous self-control and optimization. Smart products can be identified at different stages, knowing their history, real state, and suggesting alternative ways to complete. Intelligent manufacturing systems are involved in other companies' business processes, IT systems, and play an important role in the value chain within the production network [9-11].

Today's businesses store a wealth of information and data about their products, variants, manufacturing processes, workers, suppliers, customers within their enterprise software, but they are not able to complete and efficiently process data from different areas. When moving to the so-called smart production supported by smart logistics is first of all necessary to electronically record, organize, complete and create a software information network with the help of software support, which will create the possibility of management and coordination of all production and non-production operations - production, logistics, quality control, maintenance, etc. [12-14].

This information and communication system will enable us to receive and process information in real-time and to solve the necessary measures. The production manager will know exactly where the part is in the production, what operation is being carried out on it, at what stage of the production cycle it is, who is the operator at the machine, what fault occurred, what machine, when it was rectified, how long who repaired it, etc. All of this is very important information that streamlines the production process in real-time. Regarding non-production processes, information is available regarding actual costs, suppliers, customers, inventory movements and inventory levels in the entry depots, distribution depots, spare parts depots, and commissioning information. This is conditioned by the implementation of key elements:

1. implementation of sensors for continuous automatic data collection from production equipment, production lines, transport equipment, storage facilities and warehouses, materials, parts,
2. creation of an information and communication network between all objects and subjects of the enterprise's value flow,
3. application of intelligent data creation software, i.e. collecting, processing, analysing, and evaluating the collected data.

1.2 Trends in Digital Supply Chain

The goal of the Digital Supply Chain is integrated planning and management of logistics systems and networks based on digital models, methods, and tools that are built on a common flexible information and communication platform. Currently known and used tools focus on creating a digital business, where digital models can be heterogeneous, resp. usable in several projects.

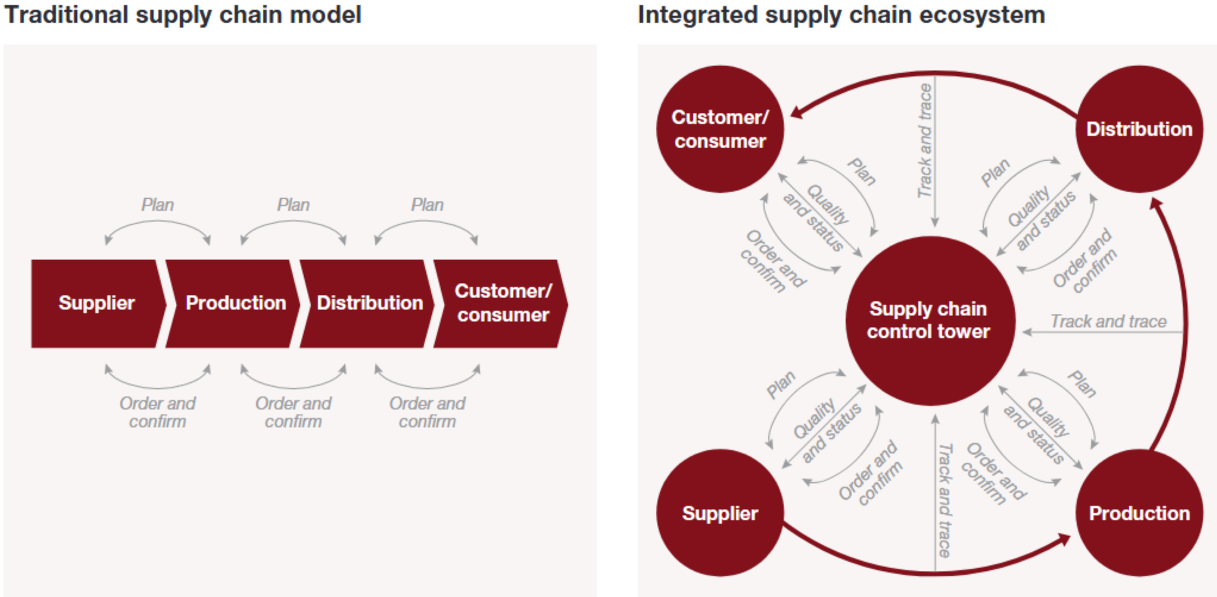

Figure 1 Complexity of Digital Supply Chain [15]

The indicator of the transformation of the supply chain into the smart supply chain is, on the one hand, the pressure from the introduction of new technologies into business processes and systems due to Industry 4.0, and on the other hand, a new concept of input procurement is being developed in combination with capacity management to ensure flexible supply dimensioning. Integrated procurement logistics aims to produce forecasts of product needs in a timely, long-term, and medium-term planning horizon. Methods and techniques for forecasting future consumption are being developed and attempted to reflect as closely and accurately as possible the course of consumption in the past. The complexity of the Supply Chain is shown in Figure 1.

Unlike traditional supply systems, the new dynamic approach to inventory management is that it considers unique procurement methods, unique demand and product flows through the production process. The aim is to define what level of inventory can provide the required level of supply service, ensure the efficiency of material flows in production, and compensate for fluctuations in demand. A key role in balancing supply and demand is the optimization of the company's inventory. The solution to the causes of overcrowded warehouses is also possible through modern information and communication technologies. It is important to gain control over what is in the warehouse and what scope of activities the warehouse provides. The aim is to provide system support for logistics processes using the principles of Lean Manufacturing, i.e. electronic records of movements of individual items in stock, material flow management upon receipt, quality control, stocking, out of stock to production, and preparation for dispatch. [15-18]. The effects of technology pressure and demand-pull in the digital supply chain are shown in Figure 2.

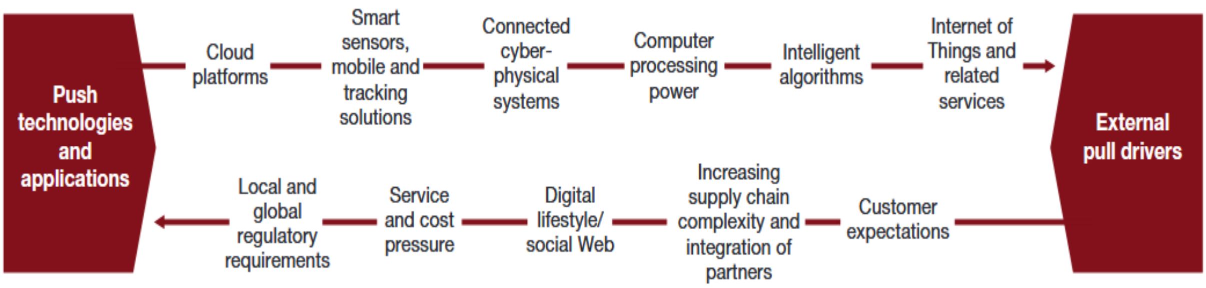

Figure 2 Effects of technology pressure and demand-pull in the digital supply chain [15]

The main benefit of introducing new information and communication technologies in combination with robotization, standardization of logistics processes is to accelerate the material flow, reduce errors in material handling and efficient use of storage areas, refine information flow, and work with information in real-time. Successful implementation of the Internet of Things in logistics technology requires intensive cooperation and a high level of participation by individual entities in creating value along the entire Supply Chain, to create a prosperous information and communication space, i.e. create an interconnected intelligent logistics network of the production process that will create added value through communication between relatively autonomous entities, thereby achieving speed, flexibility, and quality of value flow. The convergence of the physical world with the digital world is now a new paradigm of the autonomous and decentralized world of production.

2 Methodology for increasing flexibility of Supply Chain

2.1 Demand-driven Supply Chain

The disadvantage of the often-used MRP software system in practice is the lack of visibility of orders well in advance so that production and purchasing can be planned correctly. Demand in the MRP system is largely derived from the forecast. Subsequent adjustments are made near the point of the visibility of the order. End item order scheduling begins at the beginning of the planning horizon, extending the response time. The longer the so-called cumulative delivery time (procurement and production cycle), the longer the planning horizon. The longer the planning horizon, the less accurate the planning of orders, which necessitates subsequent corrections. Another element to consider is the time of customer tolerance. Ideally, it would have to be at least the same resp. higher than the cumulative delivery time. Figure 3 shows the planning time horizon vs. order visibility horizon.

MRP is a system that allows companies to quickly recalculate and synchronize total material requirements and dependencies according to a defined input demand. This is especially important for complex BOMs or many shared components. As there are currently many more connections and dependencies between the individual components, the importance of MRP, despite its imperfections, is undoubtedly growing. MRP plays an important role in the modern supply chain, but there is a need to increase its agility. The first building block on the way to achieving a more agile MRP system is to create suitable decoupling points.

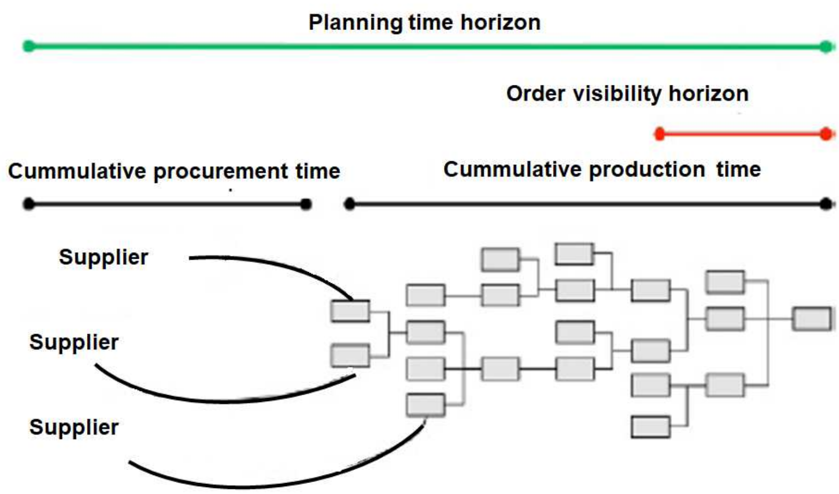

Figure 3 Planning horizon vs. order visibility [19]

2.2 Decoupling points of the logistics chain

The decoupling point helps to reduce system complexity, increase the reliability and manageability of forecasts, and increase capacity utilization, but at the expense of higher inventory costs. Factors that directly affect the location of the disconnection point can be divided into three basic areas:

- market/marketing - specific quantities of the order: demand, frequency, volatility, specific quantities of the customer: prices, quality, promptness, adherence to delivery deadlines, product variability, product customization,
- product - specific quantities of the product: product range, structure, degree of standardization, product design (customer vs. design, environmental and other requirements),
- processes/production - specific quantities: flexibility, speed, throughput, quality, type of production, service.

The suitability of the position of the disconnection point must be assessed in terms of its ability to contribute to the achievement of the company's objectives (Table 1) and in connection with the reflection of the three biggest trends in industrial production:

- co-authorship of the customer - ubiquitous access to information, more intensive competitiveness of the brand, the struggle of the manufacturer and the seller for the customer, stronger voice of the customer, a greater focus on values,
- volatility of demand - predictions are not the biggest problem - the problem is flexibility, mass

customization is expected, B-to-B to B-to-C transition, the balance of capacities by stocks, supply chain segmentation,
- complexity of supply - complexity vs. complexity, the balance between costs and delivery times, risk management challenges, supply chain segmentation, transparency, traceability, simplicity.

The above DDMRP is a methodology that seeks to eliminate the bullwhip effect in the Supply Chain by creating strategic decoupling points along the chain and sizing dynamic reservoirs in them that absorb the variability and volatility of demand. The role of storage buffers within the Supply Chain is to eliminate the impact of demand variability between planning horizons as well as the continuity of supply variability, avoiding the bullwhip effect. A very stable demand signal will be created that has the relevant information needed to effectively manage the Supply Chain, as well as several decoupling points to monitor and ensure that the plan is properly implemented. The result is an agile, yet stable, and durable Supply Chain.

Increased system stability, supported by the right demand signal, means better utilization of production capacity, smaller inventory, lower costs, faster inventory turnover, and thus higher ROA/Return on Assets. DDMRP is a Supply Chain planning and management tool that allows you to respond significantly to the market, reduce delivery time, eliminate demand variability and volatility throughout the Supply Chain, with a significant impact on ROI/Return of Investment. The term DDMRP was originally defined as the ability to know changes in customer requirements and adapt them to planning and production by introducing real-time pulling principles. In 2011 Ptak, C., Smith, CH. founded the Demand Driven Institute, which is focused on the implementation of programs in the field of education and dissemination of DDMRP into industrial practice.

3 Result and discussion

The importance of DDMRP can be explained by comparison with the most commonly used methods of inventory management in industrial practice such as Kanban - as a representative of the lean approach and the mentioned MRP system.

In Table 1 is a comparison of three methods Kanban, MRP II and DDMRP in the horizons of strategy, tactics and operations according to selected criteria.

Tab. 1 Comparison of selected criteria of Kanban, MRP II and DDMRP [19-21]

Horizon/criterium		Method		
		Kanban	MRP II	DDMRP
Strategy	Long-term planning	Capacity dimensioning, capacity balancing in excess	Strategy aimed at dimensioning and balancing the use of resources	Location and sizing of containers according to PAF/Planned Adjustment Factors
	Flow	Pull	Push (predictions)	Hybrid
	Management strategy	Decentralized planning and production	Centralized planning and production	Hybrid - centralized planning, decentralized production
	Decoupling point	All components / products	All products	Placement of strategic buffers in BOM, creation of decoupling points in the chain
Tactic	Management method	Card sizing, line balancing	MPS/Master Production Schedule	PAF/Planned Adjustment Factor
	Capacity and utilization analysis	Kanban card sizing and balancing	All BOM levels	PAF/Planned Adjustment Factors - checkpoints, increase the efficiency of WIP control
	Demand signal transmission	Kanban circuits	According to BOM	Loops between buffers and MRP integration
	Human resources management	Flexible, real-time allocation	MPS	Flexible, real-time allocation
Operative	Management of buffer	Visual management (circuits, cards)	MRP, scheduling	Demand Driven operating model
	Absorption of demand variability	Short-term flexibility	Safety stock	Buffer status, checkpoints, red zone (protection mechanism with real-time adjustments)
	Priority management	According to WIP in real time	According to the production plan	According to the state of the bins in real time
	Risk management	-	It considers only with anticipated risks	In the NFE/Net Flow Equation, spikes are considered in a limited time
	Visual management	According to the cards	-	According to colour codes

The main problem that MRP, Kanban and DDMRP methods have to deal with the management of resource variability. It can be stated that in a stable environment the results are comparable. However, when reporting demand variability (time or quantity), the MRP system shows its limits. With more significant variability, Kanban also has its limits. The goal of DDMRP is to improve the flexibility of the system at the level of strategic bullwhip effect management, tactical management of WIP/Work in process and WC/Working Capital and resources, and operational management of OTD/On Time Delivery. Strategic modelling of the DDMRP environment allows monitoring the impact of the position of the buffer on the delivery time, allows the determination of the average level of stocks for each buffer and allows analysis of ROI/Return of Investment for each buffer at the decoupling point (taking into account raw material costs). DDMRP is still at the beginning of its development, but nevertheless a number of companies that have implemented this system speak of "(r) evolution in resource and inventory management. There are many examples of world-renowned companies that have implemented DDMRP to increase flexibility in the degree of product customization.

DDMRP combines supply and demand variability into a single buffer, causing instability in lean systems. The lean systems are focused on finding the causes of problems and kaizen, which is missing in DDMRP. DDMRP does not appear as a traction system, as it does not work with current demand, but compares demand on a given day with orders on the way.

4 Conclusions

The complexity of the Supply Chain network structure will have to reflect new approaches and tools that will allow the customer to adapt, customize the product and respond in the time horizon that the customer is willing to accept while waiting for the product. Traditional demand forecasting and demand planning tools are not able to flexibly synchronize supply and demand in this way. This consideration suggests the need to change the way the Supply Chain is managed. The traditional perception of the Supply Chain, focused on the optimization of individual subsystems, is currently not optimal. The work of Smith, D., Smith, CH.: Demand-Driven Performance: The Use of Smart Metrics (2013), which focuses on the definition of supply chains as CAS/complex adaptive systems and states that they are:

- complex - a higher degree of stability is achieved through interactions between actors,
- dynamic - do not stay stable for very long,
- behave non-linearly - even a small change in the initial conditions can lead to larger impulses elsewhere (whip effect),
- adaptive and self-regulatory - that is, they evolve as a result of interaction in the system.

Self-regulation of the logistics and other entities in enterprises will be built on autonomous operation and mutual communication of machines in real-time information flows. Production process will be monitor by sensors and system integration in entire Supply Chain will enable customers to interact with the design and manufacturing process, enhance the machine and equipment availability, shorten the production cycle times, accelerate response to customer requests due to self-regulation of entering transactions. This should result in sustained productivity growth and an increase in return on assets/ROAs.

Acknowledgment
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THE COMPARISON OF TRANSPORT INFRASTRUCTURES IN INDIVIDUAL SLOVAK REGIONS BY APPLYING PCA AND CLUSTER ANALYSIS

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Keywords: transport infrastructure, regions, comparison, PCA, cluster analysis
Abstract: The development of the transport segment is currently an essential process which affects several other industries. The transport infrastructure and the services provided in this sector influence economic growth, the efforts aimed at increasing competitiveness, as well as prosperity of the society. One of the key problems Slovakia is facing is the long-term growth of differences between individual regions. The present article deals with the evaluation and comparison of selected transport infrastructure indicators in eight regions of Slovakia. The evaluation was carried out by applying basic statistical methods and multiple-criteria statistical methods. Every region was characterised by 20 selected variables describing its uniqueness (e.g. population, area, GDP per capita, road infrastructure etc.). The evaluation of similarities between individual regions in terms of selected variables was carried out by applying the Principal Component Analysis (PCA) and Hierarchical Cluster Analysis. Within the PCA, the original input variables were replaced with three principal components describing as much as 86.68% of the cumulative variance. The average linkage method, as one of the hierarchical methods, was applied to create a dendrogram representing the similarities between the regions of Slovakia. The cophenetic correlation coefficient value of CC=0.936 confirmed the proper selection of the average linkage method. The output of the cluster analysis was that 8 regions of Slovakia were divided into five similar homogenous clusters based on the examined variables. The final analysis indicated that the transport infrastructure and the development thereof significantly affect the differences between individual regions of Slovakia and, as a matter of fact, they belong to the factors creating such differences.

1 Introduction

The key preconditions and factors of social and economic development of countries and their regions include the transport infrastructure. As stated by OECD, transport infrastructure represents a key component of the economic development at all income levels and supports personal well-being and economic growth. Due to its central economic function, transport infrastructure is often referred to as a pillar of modern economy [1]. Transport infrastructure as a complex network connects towns and villages and affects human activities which interconnect social, economic and environmental systems with urbanisation and population growth [2].

According to paper [3], transport infrastructure is an integral part of the transport system in every town or country. The article emphasised the fact that as the society develops and the globalisation intensifies, the importance of transport as a factor affecting the economic and social development increases. Moreover, a transport network contributes to the social and economic development and increases the quality of life by creating intercity connections during urbanisation [4]. According to paper [5], a high quality of transport infrastructure significantly affects the transport logistics as well.

On the other hand, unreasonable planning of transport infrastructure has certain negative effects, such as increased traffic accident rate, lower transport efficiency, climate change and increased emissions of CO_2. Tang et al. monitored potential effects of changes in transport infrastructure on air quality and public health in connection with air pollution [6]. According to Doyle [7], transport is one of the most intensive sources of air pollution and may have a significant effect on public health.

A correlation between investments in transport infrastructure and regional development in 30 member states has been investigated by the OECD Programme of Research on Road Transport and Intermodal Linkages (RTR) in years 1998 to 2000 [8]. The work group analysed the evaluation studies examining the key projects dealing with transport infrastructure in OECD member states with the aim to identify the impact of investments in transport infrastructure on the regional development and improve the existing evaluation methods. Similarly, authors [9] analysed transport infrastructure and its influence on the development of regional economies in three provinces of China and obtained important data on human mobility, production-related interconnections and logistics which may subsequently be used in regional management and planning.

Hong et al. [10] stated that transport infrastructure may have various effects on economic growth in individual regions. Based on the research results, they claim that the infrastructure of land transport (including roads and railways) and water transport significantly contributed to the economic growth in the region. The influence of transport infrastructure on economic growth in regions and sectors, depending on a transport modality, was described in paper [11]. According to Gunasekera et al. [12], development of transport infrastructure efficiently reduces the journey duration and passengers and carriers significantly benefit from the saved time and reduced costs of a vehicle operation. A positive correlation between the development of transport infrastructure and economic growth was observed by Démurger [13]. Similarly, Banister and Berechman [14] stated that transport infrastructure significantly affects economic growth of a country. A support of regional development in the eastern part of Macedonia and Thrace in Greece through the road transport projects has been discussed by Mavraki et al. [15]. In the article, the authors described the analysis of the extent to which road transport projects, implemented within the Greek National Strategic Reference Framework (NSRR) for 2007-2013, contributed to the economic development in the analysed region. The influence of transport infrastructure on regional economic growth in 31 provinces in China in years 1998 to 2007 was dealt with by authors of paper [10]. Based on the analysis, the authors assumed that transport infrastructure plays an important role in economic growth. The role of the infrastructure in the regional development strategy was discussed in paper [16] by means of a case study of the Netherlands, and the analysis was carried out by applying selected statistical methods (e.g. cluster and scaling methods). Authors [17] introduced a new Road Funding Priority Index (RFPI) as a tool to be used in decision-making on road building projects of high priority. Relevant indicators are selected on the basis of, among other factors, the Principal Component Analysis (PCA). Monitoring effects of selected indicators of regional macroeconomy on the development and planning of transport infrastructure using neutron networks was presented by authors of paper [18]. Authors selected important macroeconomic indicators by applying the Principal Component Analysis. Paper [19] dealt with monitoring and control of urban traffic. Identification of critical traffic points is also based on the PCA.

High-quality and functional transport infrastructure is one of the key preconditions for the fast development of regions in the Slovak Republic. Article [20] deals with the transport sector as a part of the infrastructure in EU countries, especially in Slovakia. According to paper [21], Slovakia exhibits regional differences in quality of individual transport networks, and this has far-reaching consequences for the growth of economic and social differences between individual regions in the country. Authors Masarova and Ivanova [22] compared road infrastructures in Slovakia and Poland in years 2005 through 2013 and pointed out regional differences in road infrastructure between those two countries. The trends developing in the road and railway transport in the Slovak Republic were analysed in article [23] by applying statistical methods. Authors Brumercikova and Bukova applied the regression and correlation analysis to the evaluation of the public passenger transport in the Slovak Republic [24]. According to Golias [25], the Slovak Republic is one of the countries with the greatest regional differences in income indicators based on OECD data for 2014. Document [26] described individual regions from several points of view; authors stated that in less developed regions the transport infrastructure was of inferior quality and this impaired the local business environment.

The transport segment began to develop in Slovakia after the country joined the EU. Hence, Slovakia was allowed to receive finances from the European funds for the purpose of transport infrastructure development. In 2013, Phase I of the preparation of the strategic transport infrastructure development plan was implemented as this was a requirement to be met by Slovakia in order to be able to use the finances from the European funds. The ongoing Phase 2 is not focussed merely on the development of the transport infrastructure, but on the complex development of the entire transport sector in the Slovak Republic [27].

Development of Slovakia is closely connected with a functional transport infrastructure. The key factors which significantly affect the quality thereof include also regional social and economic conditions. The purpose of the article is to compare regions of Slovakia in terms of transport infrastructure and selected social and economic indicators which characterise the regions. The result of the analysis is the formation of homogeneous clusters of regions with similar characteristics on the bases of selected indicators.

2 Methodology

2.1 Slovakia

Slovakia (Slovak Republic) is an inland country in Central Europe (Figure 1) with the total area of 49,035 km². The population is approximately 5.45 million inhabitants. The capital is Bratislava. Since 2004, it is a member of the European Union.

The road structure in Slovakia consists of motorways, expressways and roads of Classes I, II and III. Highways, expressways and Class I roads are roads of international as well as national importance which represent the basis of the road network in Slovakia. According to the Strategic Development Plan of Road Infrastructure in Slovakia until 2020 [28], motorways and expressways connect important places in the country, while the motorways also connect Slovakia with neighbouring countries. They are mostly built on the routes with the most intensive traffic burden.

Class II roads interconnect the centres of the regions and usually supplement the network of motorways, expressways and Class I roads. Class III roads represent the longest part of the road network. They are roads of regional to local importance and interconnect villages and the higher-level road network [29].

Figure 1 Slovakia and neighbouring countries

In 2018, the total length of the Slovak road network managed by the state amounted to 18,059 km. The largest component of the road network represented Class III roads (10,358 km; 57.4 %). In 2018, motorways and expressways represented only 4.3 % of the road network (778 km out of 18,059 km). Class I roads represented 18.3 % of the total length of the road network (3,311 km), and similar percentage was observed for Class II roads (3,610 km; 20 %). In 2018, 3,580 km of railway lines were used [28].

At present, Slovakia consists of eight regions (Bratislava Region SK-BL, Trnava Region SK-TA, Nitra Region SK-NI, Trenčín Region SK-TC, Žilina Region SK-ZI, Banská Bystrica Region SK-BC, Prešov Region SK-PV and Košice Region SK-KI), 79 districts, 140 towns and 2,933 villages (Figure 2).

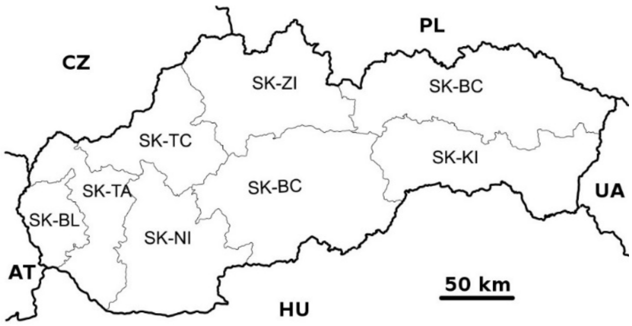

Figure 2 Regions in Slovakia [30]

The analysis of differences between individual regions in Slovakia in terms of transport infrastructure was carried out while considering several input variables: transport infrastructure by regions (motorways and motorway feeder roads, expressways, roads of Classes I, II and III; construction length of operated railway lines); and transport operating indicators by regions (motorisation rate, number of cars, trucks, buses and truck tractors). The motorisation rate expresses the number of passenger cars relative to the total number of inhabitants.

For the purpose of a more complex assessment of the regions, the analysis was carried out while using the data on the region area and population, and the indicators characterising a social and economic level of the region (average age, ageing index, regional GDP per capita, unemployment rate and average monthly nominal wage). The average age represents the weighted arithmetic mean of the number of years lived by inhabitants to a certain date. It is the average age of the living inhabitants. The ageing index (Sauvy's index) expresses the number of persons in the post-productive age (65+ years) per 100 people in the pre-productive age (0–14 years). The productive age percentage is the percentage of inhabitants who are economically active. The list of selected input variables is presented in Table 1.

Table 1 Selected input variables in regions

Designation	Description	Designation	Description
A1	Country area (km^2)	A11	Class I roads (km)
A2	Population (number)	A12	Class II roads (km)
A3	Average age (year)	A13	Class III roads (km)
A4	Ageing index (%)	A14	Motorisation rate
A5	Percentage of productive age (%)	A15	Number of cars (pc)
A6	Regional GDP per capita (Euro/1 inhabitant)	A16	Number of trucks (pc)
A7	Average nominal monthly wage (Euro)	A17	Number of buses (pc)
A8	Unemployment rate (%)	A18	Number of truck tractors (pc)
A9	Motorways and motorway feeder roads (km)	A19	Number of transport and warehousing companies (pc)
A10	Expressways (km)	A20	Construction length of operated railway lines (km)

The analysis was carried out while using the 2018 data which are publically available in the statistics published on the website of the Ministry of Transport and Construction of the SR [31] and at the Central Office of Labour, Social Affairs and Family [32], as well as the data from the database published at Datacube.stastistic.sk [33].

2.2 Statistical methods

The analysis of selected variables characterising the regions in Slovakia was carried out by applying basic statistical methods and multidimensional statistical methods: Principal Component Analysis and Cluster Analysis.

Correlations between variables and PCA

The correlations were investigated using the correlation matrix which does not require the input data to be expressed in identical units. A correlation between two variables is represented in the correlation matrix by means of the Pearson's correlation coefficient *r*. In order to determine the rate (degree) of the dependence, the scale that may be applied is as follows: no correlation ($|r| < 0.29$); weak correlation ($0.30 < |r| < 0.49$); moderate correlation ($0.50 < |r| < 0.79$); and strong correlation (S, $0.80 < |r| < 1$). If the correlation coefficient *r* is positive (or negative), it means that there is a direct (or negative) linear correlation between the variables.

Principal Component Analysis (PCA) belongs to multidimensional analysis methods. The purpose of this method is primarily to reduce the number of input dependent (correlated) variables at the lowest possible loss of information. New latent variables, i.e. the principal components, are not mutually dependent and represent a linear combination of the original variables. Every principal component is characterised by a rate of variance. The first principal component accounts for the largest possible variance of the original values. The contributions of the other principal components to the variance are always lower. An adequate number of principal components may be identified by applying several methods. The one frequently used in practice is the Kaiser-Guttman rule which takes into consideration all eigenvalues higher than 1. Another rule recommends considering only those principal components which explain 70 to 90% of the cumulative variance [34].

Cluster analysis

A cluster analysis belongs to multidimensional statistical methods that deal with similarities between multidimensional objects and it comprises dividing the objects into homogeneous groups, i.e. clusters [35]. The information on such similarities is obtained through various metrics of estimated distances between two objects (e.g. Euclidean distance). Depending on the method of forming such homogeneous groups, we distinguish between hierarchical and non-hierarchical methods. Hierarchical clustering methods are based on gradual grouping of objects, ranging from the most similar to the most different objects. There are several methods of hierarchical clustering (e.g. the nearest neighbour method, the furthest neighbour method, the average linkage method, Ward's method etc.). A graphical representation of hierarchical clustering is a tree referred to as a dendrogram. All the results were obtained using the R-package software.

3 Result and discussion

The research was carried out with the aim to:

- Analyse the input variables by basic statistical methods and PCA;
- Compare the regions in Slovakia in terms of their road infrastructure and other parameters characterising individual regions by applying a hierarchical cluster analysis.

3.1 Characteristics of variables and PCA method

The structure of road networks in the regions of Slovakia existing in 2018 is shown in Fig. 3. In all regions, the roads representing the highest percentage of the road network were the Class III roads (44–60%; A10). The data indicate that Nitra Region (SK-NI) and Banská Bystrica Region (SK-BC) comprised 0 km of motorways and motorway feeder roads. The highest percentage of motorways and expressways was in Bratislava Region (SK-BL, 14%).

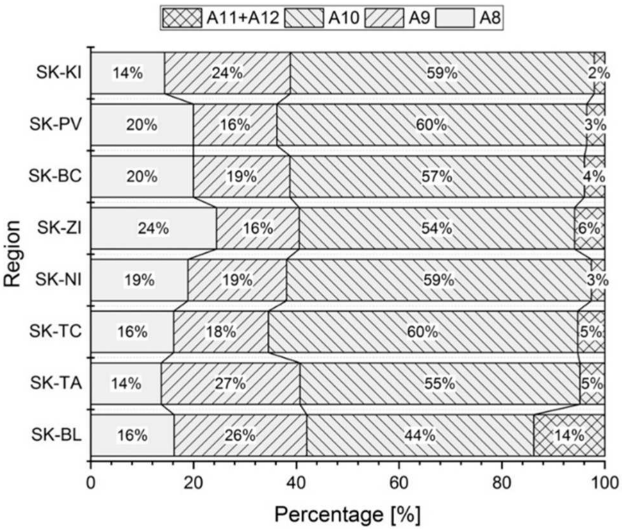

Figure 3 Road networks in regions of Slovakia [%]

Other additional data on the regions of Slovakia (area, population, average age, ageing index, percentage of productive age, regional GDP per capita, average monthly nominal wage and unemployment rate) are listed in Table 2.

Table 2 Regional characteristics

Region	Regional characteristics							
	A1 [km^2]	A2 [number]	A3 [year]	A4 [%]	A5 [%]	A6 [euro/1 inhabitant]	A7 [euro]	A8 [%]
SK-BL	2052.2	655,218	40.92	97.67	66.08	38,836.00	1,330	2.62
SK-TA	4146.6	562,982	41.72	114.39	68.96	17,917.48	1,005	2.31
SK-TC	4502.0	586,623	42.50	128.30	68.54	13,741.78	984	2.93
SK-NI	6343.8	677,682	42.49	128.56	68.73	13,768.71	880	3.12
SK-ZI	6808.7	691,196	50.27	96.88	69.04	14,048.54	946	4.04
SK-BC	9454.4	648,831	41.70	114.77	68.41	12,064.00	912	7.03
SK-PV	8973.9	824,424	38.59	77.28	68.15	10,388.51	813	8.61
SK-KI	6754.5	799,816	39.53	86.13	67.97	13,352.94	957	8.17

The first step of the analysis of the parameters was to search for any potential correlations between individual input variables. Because the values of the variables were expressed in different units, the correlations between them were identified using a correlation matrix (Figure 3), while the correlations between two different variables were identified using the correlation coefficient *r*.

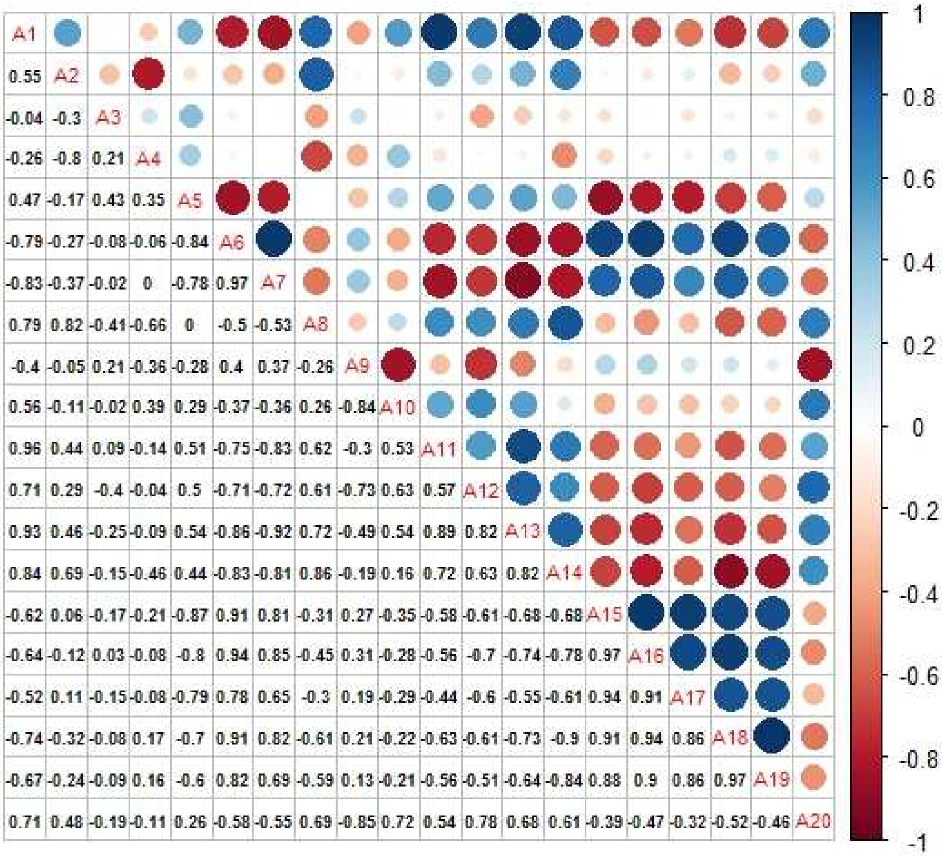

Figure 4 Correlation matrix (R package)

The resultant correlation matrix (Figure 4) indicates, for example, that there is a very strong direct correlation (0.80 <|r|<1) between variables A11 and A1 (r=0.96); A13 and A1 (r=0.93); A16 and A6 (r=0.94); A16 and A15 (r=0.97); A18 and A16 (r=0.94); A17 and A15 (r=0.94); and between A19 and A18 (r=0.97). Moreover, several variables exhibited very strong indirect correlations, e.g. A19 and A14 (r=-0.84); A10 and A9 (r=-0.84); and A13 and A (r=-0.92). It seems that there are relatively strong correlations between multiple pairs of variables. Therefore, new independent variables were determined by applying the Principal Component Analysis (PCA).

Within the PCA, the original input variables were replaced with new independent variables, i.e. the principal components. The main components were identified using the eigenvalues depicted in a scree plot (Figure 5). The eigenvalues and variability of PCA components for 7 new components are listed in Table 3.

The eigenvalue of the first principal component Dim1 was 11.39, the second was 3.40, and the third component exhibited the eigenvalue of 2.54 (Table 3). The first component Dim1 described approximately 56.93% of the cumulative variance of data. The second component Dim2 explained 17.02 % and the third component Dim3 explained 12.72% of the cumulative variance of data. These three principal components explained altogether as much as 86.68% of the cumulative variance. Therefore, the first three components represented the new input variables.

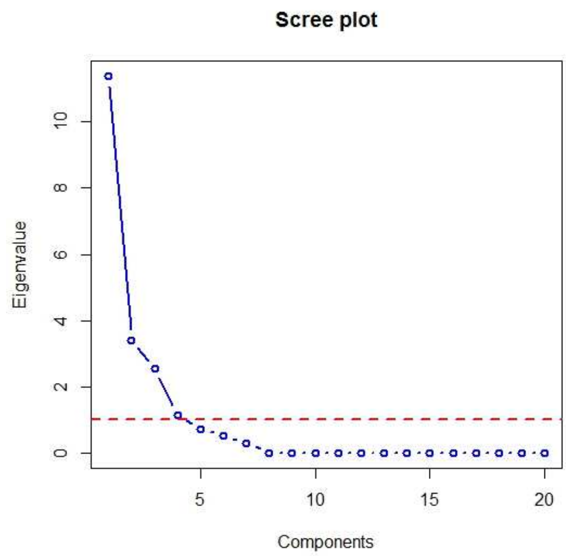

Figure 5 Scree plot (R package)

Table 3 PCA results

Components	**Dim1**	**Dim2**	**Dim3**	**Dim4**	**Dim5**	**Dim6**	**Dim7**
Eigenvalue	11.39	3.40	2.54	1.14	0.71	0.51	0.30
Variance (%)	56.93	17.02	12.72	5.72	3.57	2.54	1.49
Cumulative Variance (%)	56.93	73.96	86.68	92.39	95.97	98.51	100.00

Coefficients of eigenvalues, i.e. the component coefficient matrix, for the first three principal components are listed in Table 4. The first component Dim1 mostly consisted of the variables describing transport infrastructure in regions (A1, A5, A6, A7, A8, A11 through A20, the highlighted numbers in Table 4). The second principal component Dim2 consisted mainly of the variables related to population (A2), average age (A3) and ageing index (A4). The last principal component Dim3 consisted mostly of motorways (A9) and expressways (A10).

Table 4 New input variables identified by PCA

Principal components	**Original variables (Part 1)**									
	A1	**A2**	**A3**	**A4**	**A5**	**A6**	**A7**	**A8**	**A9**	**A10**
Dim1	**0.90**	0.39	-0.05	-0.10	**0.70**	**-0.95**	**-0.93**	**0.70**	-0.47	0.50
Dim2	0.24	**0.85**	**-0.54**	**-0.81**	-0.63	0.20	0.08	0.69	0.04	-0.14
Dim3	0.07	-0.18	-0.30	0.47	-0.12	0.09	0.06	-0.04	**-0.83**	**0.77**

Principal components	**Original variables (Part 2)**									
	A11	**A12**	**A13**	**A14**	**A15**	**A16**	**A17**	**A18**	**A19**	**A20**
Dim1	**0.81**	**0.82**	**0.92**	**0.89**	**-0.86**	**-0.90**	**-0.77**	**-0.92**	**-0.85**	**0.72**
Dim2	0.13	0.10	0.16	0.32	0.46	0.28	0.43	0.10	0.12	0.28
Dim3	0.05	0.40	0.16	-0.29	0.18	0.18	0.24	0.33	0.36	0.51

A graphical representation of the data on the original variables in the coordinate system of the first principal component Dim1 relative to the second principal component Dim2 is shown in Figure 6.

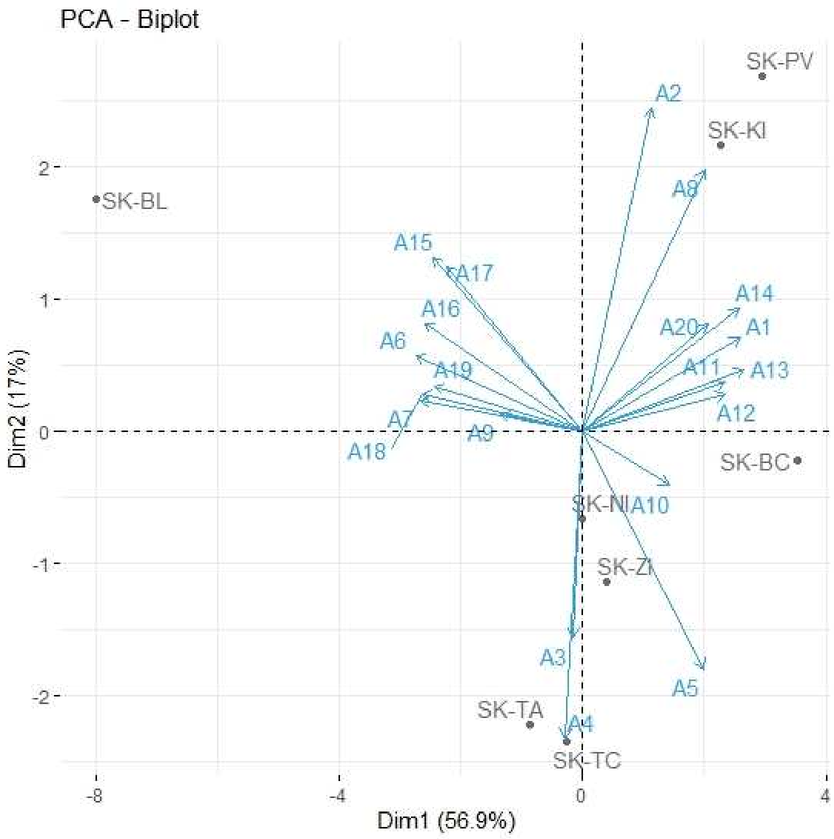

Figure 6 Biplot. (R package)

It seems that SK-BL region (Bratislava region) deviates from the other regions (Figure 6). The graph indicates a similarity between SK-PV region (Prešov Region) and SK-KI region (Košice Region). An analysis of the results of PCA facilitated identification of certain similarities between other regions: SK-TC (Trenčín Region) and SK-TA (Trnava Region).

3.2 Cluster analysis

A comparison of the regions of Slovakia in terms of selected transport infrastructure, as well as other analysed variables, was carried out by applying the cluster analysis. The input variables were three new independent variables (three principal components - Dim1, Dim2 and Dim3) obtained by PCA. These variables also represented, to a large extent, the road infrastructure in a given region. The Euclidian distance was used as a distance measure. Four different agglomerative hierarchical clustering methods were gradually applied: the average linkage method, the nearest neighbour method, the Ward's method and the median method.

The best clustering method was identified using the cophenetic correlation coefficient; the resultant value thereof indicated that the best clustering method was the average linkage method (the average linkage method: CC=0.936; the nearest neighbour method: CC=0.930; the Ward's method: CC=0.907, the median method: CC=0.886). An output of the cluster analysis was the formation of homogeneous clusters of analysed regions, as depicted in a dendrogram (Figure 7).

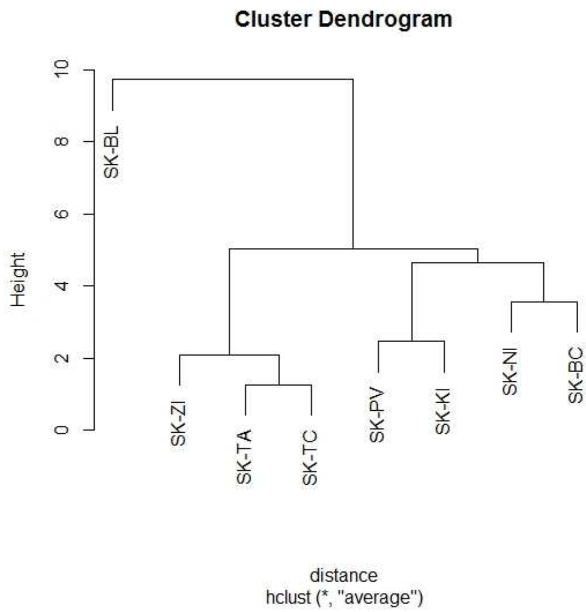

Figure 7 Dendrogram – the average linkage method (R package)

The dendrogram (Figure 7) indicates that SK-BL region (Bratislava Region) represented a separate cluster. Similarly, SK-ZI region (Žilina Region) may be regarded as a separate cluster, but with certain characteristics similar to those of other two regions - SK-TA (Trnava Region) and SK-TC (Trenčín Region). SK-PV (Prešov Region) and SK-KI (Košice Region) regions formed a separate cluster. Another separate cluster consisted of SK-NI (Nitra Region) and SK-BC (Banská Bystrica Region) regions. The result of the clustering is shown in Figure 8. Regions forming one cluster are designated with the same colour.

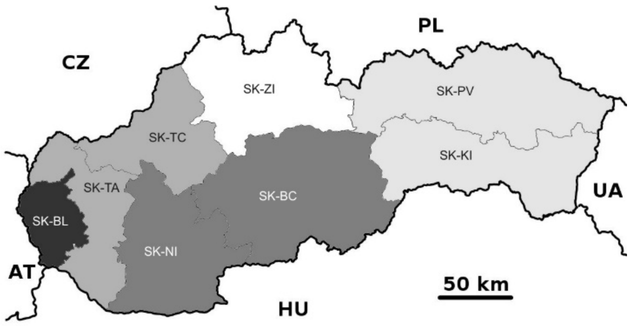

Figure 8 Cluster analysis result – division of regions

Bratislava Region (SK-BL) exhibited significant differences from the other regions. This region is the most developed region in Slovakia; in 2017, it held 8th place in the EU in terms of GDP per capita, amounting to 179% of the EU average value [36]. Its strengths include strong economic interconnection with the capital city, closeness to cities like Wien and Budapest, relatively advanced transport infrastructure and presence of investment capital. This is also related to better business and transport infrastructure. Other regions, especially the regions in Eastern Slovakia (Prešov Region SK-PV and Košice Region SK-KI) are far behind the Bratislava Region (GDP per capita amounted only to 54% of the EU average).

Žilina Region (SK-ZI) belongs to regions which are mostly industrial. It has a convenient geographical location on the most important roads and railway lines connecting the western and eastern parts of Slovakia. Trnava Region (SK-TA) benefits from its geographical closeness to the fast-developing Bratislava Region and from the advanced transport infrastructure. Trenčín Region (SK-TC) is one of the most industrial regions of Slovakia. Nitra Region (SK-NI) is the most developed agricultural region in terms of the agricultural land area (more than 74% of the region area) and productivity rate of the local agricultural production. Banská Bystrica Region (SK-BC) is relatively less developed and its southern part is mostly agricultural with food production. A geographically rugged terrain in this region hinders the construction of adequate transport infrastructure.

Košice Region (SK-KI) is a region with a relatively developed economy. It is a centre of several industries, including metallurgy, mechanical engineering, electrotechnology and food production. However, Košice Region contains the least developed districts of Slovakia. Prešov Region (SK-PV) is a less developed region with a persistently high unemployment rate and significant economic and social differences when compared to other regions. The problems of this region are even deepened by poor transport infrastructure.

4 Conclusions

Adequate transport infrastructure is a key precondition for the transport system of a country and is crucial for the sustainable economic growth. Using the available data, it was possible to compare individual regions in Slovakia. The result of the applied statistical methods was the formation of clusters based on similarities between the regions while considering primarily the influence of transport infrastructure. It seems that the regions may be divided into four to five groups of regions that exhibit similar characteristics. The region where Bratislava, the capital of Slovakia, is located, exhibited the most marked differences. The analysis showed that the quality of transport infrastructure significantly affects regional differences in Slovakia, and to certain extent it even causes such differences.

A complex comparison of regions indicates a direct correlation between the quality and functionality of transport infrastructure and a social and economic level of a particular region. In regions with more accessible and more developed transport infrastructure, the social and economic conditions for the inhabitants are better.

It is therefore essential to pay attention to the development of transport infrastructure in these regions. Furthermore, it is very important to regard as a priority to complete the construction of the road interconnecting the eastern and western parts of the country, the road representing a south-north axis of the country, as well as the road connecting the south and north of Eastern Slovakia. Another very important objective is to complete the construction of roads connecting Slovakia with its neighbouring countries. Slovakia is an important transit territory where the differences between individual regions are largely demonstrated. A region which is important for transit transport is the one around Bratislava (near Budapest and Wien) and Žilina Region (near the north-east of the Czech Republic and the south of Poland). Regions in southern and eastern Slovakia are distant from the main transport routes. However, these regions in particular have great potential thanks to their location with regard to the neighbouring countries.

All the above-mentioned objectives represent the visions and priorities of transport infrastructure which are currently discussed in the Slovak Republic. Development of transport infrastructure of this country is a comprehensive process accompanied with high costs and technological requirements. Measures aimed at completing motorways and motorway feeder roads, extending transport capacities and improving the quality of existing roads will lead to the development of transport infrastructure. Access to high-quality and efficient transport infrastructure in all regions will facilitate elimination of regional social and economic differences and improvement of competitiveness of the country's economy.

Authors regard the monitoring and identification of the impact of transport infrastructure on selected social and economic factors in individual Slovak regions as a promising direction to take. It will also be interesting to monitor the achievement of the objectives within the strategic transport development plan within a few following years and evaluate an expected positive impact thereof on changes in the existing regional differences.

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INTEGRATED APPROACH IN ORGANIZING LOGISTIC ACTIVITY

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Abstract: The main theoretical aspects of the features of the formation of the logistics activities of organizations in the modern conditions of the transformation of the world market are considered. The conceptual necessity of using an integration approach in organizing logistics activities, taking into account the influence of factors of the macroeconomic environment, has been substantiated. The main aspects and features of intrafirm and interfirm logistic integration of organizations are interpreted and reasoned, which, in contrast to existing approaches, makes it possible to distinguish this process from its influence on the main activity, taking into account the risk factors. The conceptual factors contributing to the formation of integration processes in the organization in modern conditions of the transformation of the world market are highlighted. It is argued that the modern realities of doing business, regardless of the type of economic activity, necessitate the use of an integrated approach in management when organizing logistics activities. With the help of economic and statistical analysis of the logistics services market in the world, the intensity and need for the use of intrafirm logistics integration are substantiated. The developed theoretical and methodological approach of the integration organization of logistics activities can be applied in practice, taking into account the peculiarities of the economic activities of organizations in modern conditions.

1 Introduction

The globalization processes of the global economy intensify the need to search for innovative ways and forms of business organization. These processes greatly complicate the relationship, between participants in the processes of production, distribution and exchange as a result of a number of systemic changes and trends in the global economy, which necessitates the application and use of more innovative approaches to management. Logistic activity is no exception and requires the use of an integrated approach in its functionality, which involves combining various functional areas and their participants within a single logistics network in order to optimize it.

It is worth noting that it is the desire to unite in a holistic process: supply, production, distribution, is the only possible prospect in solving the issues of achieving goals within the logistics system at the micro level, and managing end-to-end material flow, starting from the end user and covering all suppliers of goods, services and information that add value to consumers and other interested parties, at the macro level. It should be noted that all macroeconomic imbalances and trends in changing the global economy affect the development of logistic detail, which in turn leads to a reduction in the product life cycle and decision-making time, which determines the relevance of the integrated approach to organizing the logistics activities of organizations.

1.1 Theoretical aspects of the development of an integration approach in the organization of logistics activities of organizations

The relevance and need to study this issue have been observed for many years. The main theoretical aspects of the application of the logistic approach in managing the organization are considered in the writings of the group of the following scholars such as: [1-6], which distinguish logistics as a separate science of management and consider the basic conceptual provisions of its effective organization. However, the presented views do not quite correspond to modern realities and take into account all the main challenges that top-management companies face in modern business conditions and require more detailed analysis and research. Particular attention in the basic principles of organizing logistics activities deserves the approach of a group of scientists: [7-14], which consider the principles of organizing the logistics of organizations based on the basis of an integrated approach to management based on institutionalism. This approach is fundamental in this direction but does not take into account the whole range of factors affecting the management process and requires a more in-depth study. There is a fairly large number of studies in the field of logistics and its organization in various aspects and types of economic activity, we consider the main approaches in these studies.

The main aspects of ensuring the effectiveness of the logistics of organizations are considered in the scientific works of scientists: [15,16], who believe that the organization of logistics activities of organizations should always be effective, which will ensure the competitiveness and profitability of the organization. Features of the impact of information technology in integrated logistics are given attention in the works [17], and the study of integrated logistics strategies [18], the relationship of strategies, structure, process and performance in integrated logistics as an integrated production process [19-21]. These approaches conceptualized the main aspects of the use of logistics in economic sectors and its main features, but do not take into account the volatility of the environment, which has a significant impact on the logistics process of the organization.

The development of integration processes in logistics activities contributed to the selection of research topics regarding relations with integrated logistics and customer service by the following group of scientists: [22-25], which made it possible to determine the need for building the logistics process as an inextricable process of organization, which is quite relevant in modern business conditions. Outsourcing of integrated logistics functions was considered by scientists: [26-28], who believe that the effective organization of logistics is the use of outsourcing services, but in modern conditions this does not always allow achieving the strategic goals of the organization. The main issues of improving third-party logistics through integrated management are considered in the work of a group of scientists: [24,26,29], which highlight the need to use an integrated logistics management approach for an organization, but not a unified approach to this process. However, despite numerous scientific studies, many vague and debatable issues remain within the framework of organizing an efficient organization logistics process and the key specifics of an integrated approach in logistics, which helps to unify functional different areas and their participants within a single logistics system in order to optimize it, which requires more in-depth analysis and research.

One of the main economic trends is the formation of new factors in the effectiveness of logistics, the transformation of its traditional areas of application and the emergence of a qualitatively new strategic innovation system. It should be noted that in economically developed countries, logistics has long been considered a strategically important component of the economy, which is quite reasonable, since the resource model and fragmented logistics have been replaced by innovative, which is based on information, organizational and infrastructure integration in supply chains. Long-term success in the market and increased competitiveness is facilitated by the integration of logistics at various management levels. Integration as an economic category is the process of achieving the unity of efforts of various subsystems in fulfilling the organization's tasks, both of a full cycle, including design, production, and distribution of products and services [26]. However, this development process, which is directly related to the unification of individual parts into a single whole, which allows for the long-term rapprochement of their general goals.

1.2 Features of the organization of logistics activities of organizations in modern conditions

The integrated approach creates a real opportunity to combine the functional areas of logistics by coordinating the actions performed by the independent links of the logistics system, sharing a common responsibility within the framework of the objective function, which is a source of customer value and competitive advantage. The process of improving the relationship of business entities based on systemic principles with the extraction of the economic effect for both enterprises and consumers determines the usefulness of logistics integration. It is integration (cooperation) that minimizes overhead costs and duplication of functions. In general, it should be noted that the integration of logistics allows companies and their partners in the supply chain to act as a whole, which lead to increased productivity throughout the chain. For a more detailed study of the logistics features of organizations in modern conditions, it is necessary to consider the main stages and components of the logistics process, which are presented in Figure 1.

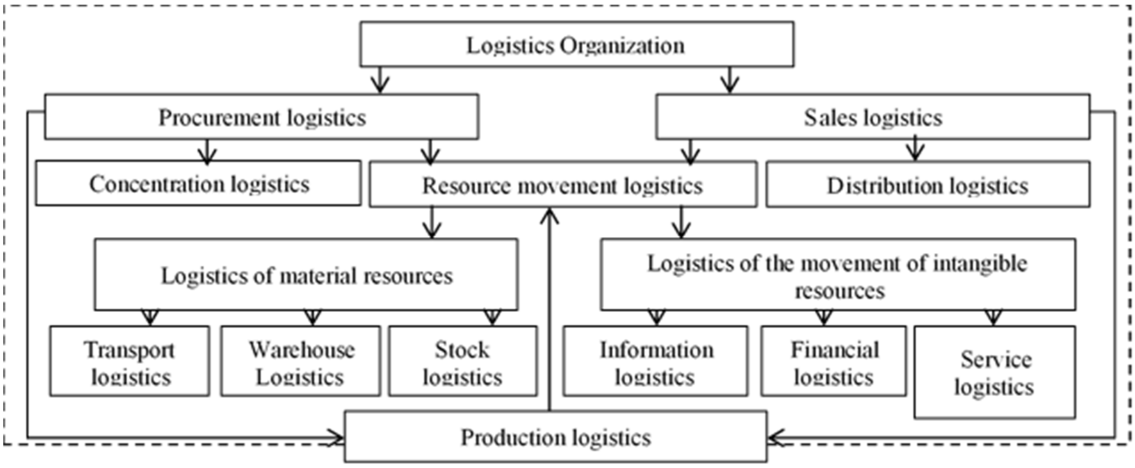

Figure 1 The main stages and components of the logistics process of the organization in modern conditions
Source: Developed by the author

Logistics is seen as a field of competence that connects a company with its customers and suppliers. Consumer information flows (and from them) enter the company in the form of sales data, forecasts and orders. This information is translated into specific production and procurement plans. The incoming material resources begin the flow of stocks, which gradually acquire added value, the movement of which ends with the transfer of ownership of finished products to consumers. Thus, in this single process, two components are distinguished: the stock flow and the information flow. The main aspects of logistics integration are presented in Figure 2.

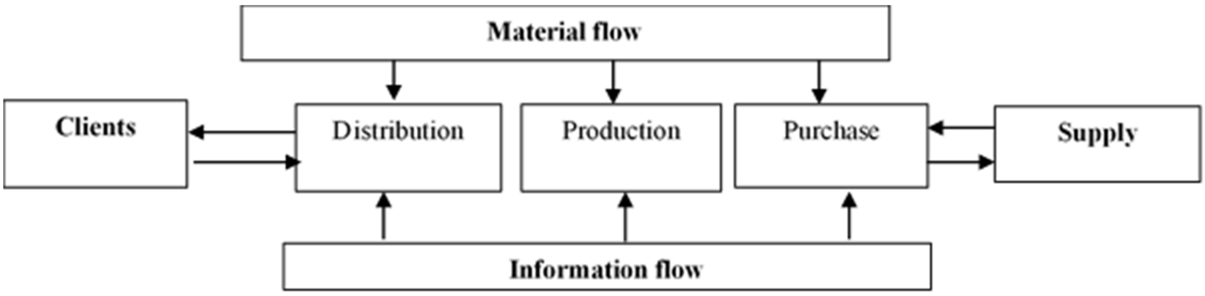

Figure 2 Integration of logistics activities of the organization
Source: Developed by the author based on [16]

Studying the specifics of integrated logistics [20] and [26] they focus on the following main aspects: 1) integration of such integrators as the process, management-marketing concepts, material and information flows; 2) the main focus is on overall efficiency, and not on the performance of individual logistics links; 3) management of production, distribution and supply are combined, i.e. all possible disagreements between functional areas and corresponding departments are eliminated; 4) minimizes the contradictions between the manufacturing sector and marketing; 5) there is a systematization and streamlining of information flows.

It should be noted that based on the functional principle, integrated logistics promotes the involvement of all structural divisions in ensuring the product life cycle, starting with the development of an idea and ending with an after-sales service. Thus, two areas of integration in logistics can be distinguished: 1) intra-company integration involves the integration of logistics functions at the enterprise level; 2) intercompany - facilitates integration across the entire supply chain. Common to these integrations is the cross-functional focus. The peculiarity of integrated internal logistics is the creation at the enterprise level of the conditions for the interconnection of supply logistics, internal production and distribution logistics.

2 Methodology - Peer Review Process

The globalization of the world financial market and the high level of risks that are generated by the processes of uncertainty and volatility, both external and internal environment of organizations, necessitate a revision of existing tools and approaches to management. This transformation and necessity also influenced the peculiarities of the conduct and principles of organizing the logistics activities of organizations. In order to determine the theoretical aspects of the development of logistics activities of organizations, taking into account the transformation of the financial market, the main methods of theoretical generalization and comparison are used in the work. To form a unified approach, tools were used in structural and logical analysis in order to highlight the key tools of the logistics activities of organizations and the main directions in the development of integration management. The methodological component was the data on the grouping of countries by the level of development of the international logistics index. On the basis of economic and statistical analysis, conceptual factors are identified that contribute to the formation of integration processes in an organization in modern conditions. With the help of economic and statistical analysis of the world logistics market, the intensity and necessity of using intra-firm and inter-firm logistics integration are substantiated.

3 Result and discussion

This interconnection is carried out in the form of a single end-to-end function that implements the functional cycle of logistics. Intercompany integrated logistics guarantees, on a supply chain scale, the interconnection of all types of logistics activities between participants. The interaction is carried out in a consistent manner in the form of a single end-to-end function until the final need is satisfied, i.e. networks are being created to integrate logistics functions. The effectiveness of intercompany integrated logistics ensures compliance with the following rules: all participants in the same supply chain must cooperate to maximize the satisfaction of the end user of the enterprise, while avoiding competition in the supply chain. As noted by a group of scientists [15] and [26], they emphasize the intercompany integration of managerial actions, which is based on an agreement between independent enterprises that compensates for weaknesses and creates sustainable competitive advantages and contributes to achieving a synergy effect. Among the main prerequisites that contribute to the activation of the integration processes of the participants in the logistics market, it should be noted: 1) the development of information technologies, allowing, on the one hand, to effectively manage all areas of production and business; and on the other, to reduce logistics costs; 2) assessment of logistics services by consumer enterprises as a strategic element in the development and implementation of competitive advantages, respectively, a better (informed) choice of logistics operators; 3) prospects and trends for the introduction of new organizational forms - logistics networks; 4) understanding of logistics as a tool for creating and implementing competitive advantages.

Companies and organizations that use an integrated logistics approach are united into logistics networks and get a number of opportunities, such as: rationalization (optimization) of logistics processes and operations, leading to lower logistics costs for all participants in the logistics market; expanding the range of logistics services through the introduction and development of new technologies of logistics processes; increasing the number of customers for all integration partners; reduction of logistic risks; improving the quality of the logistics services provided, without increasing its cost to consumers; strengthening the competitive position of logistics operators in the logistics services market. It should be noted that the logistics services market may also be involved in the integration process. In this context, the integration process is aimed at strengthening ties between business entities, that is, consumers and suppliers of logistics services, as well as the state, combining them into a single whole. As noted, [26,27], not all companies can perform a full range of logistics operations. Typically, firms use the logistics services of third parties, that is, companies transfer part of their logistics functions to third parties. It is the ability to ensure the fulfilment of a particular logistic function that has become the main classification element of companies - logistics intermediaries.

Based on multifaceted scientific research, it is worth noting that most often they resort to third-party organizations to carry out the following logistic functions: providing information on tracking cargo and managing transportation; check cargo invoice; organization of freight traffic from ports or to ports; customs clearance and customs declaration; preparation of freight and export-import documentation; Warehousing local transport coordination (on the basis of the shipper); negotiation of transport tariffs; communication with foreign suppliers; assembly, testing of products, as well as marking and other operations; selection and verification of the reliability of the performance of their duties by the freight carrier.

The market of logistics services at the present stage is characterized by a process of fundamental changes that have a cardinal effect on the scale, role of the activities of its participants, as well as the structure of their relationship. The level of service and, as a result, the structure of the organization of classes of logistics operators (1PL, 2PL, 3PL, 4PL, 5PL) are dictated by the global logistics market and the need of companies for this type of service. In modern business conditions, the growth of the global logistics market is due to the following factors: 1) the development of international trade flow; 2) globalization of the economy; 3) the desire of enterprises to optimize costs in all parts of the supply chain; 4) the concentration of enterprises on activities related to key competencies and outsourcing of non-core areas in their work; 5) an innovative approach to product distribution and marketing (electronic methods and ways of doing business).The rating of countries by gradation of the international logistics efficiency index as of 01.01.2017 is presented in Figure 3.

The development trends of the logistics services market are confirmed by the results of annual research. Among them, a number of major foreign resources can be distinguished: an annual analytical review of the results of the development of logistics according to the World Bank methodology (Logistics Performance Index); Logistics Market Development Index in Emerging Economies, developed by the Transport Intelligence Research Institute (UK); Annual State of Logistics Report provided by the Council of Supply Chain Management Professionals. The annual analytical review of the results of logistics development using the World Bank methodology (Logistics Performance Index) is compiled in order to identify problems and opportunities in the field of logistics efficiency by measuring the convenience of the logistics system.

The calculation of the logistics performance index for each country is based on surveys of regional, national and international logistics operators, freight forwarding companies that provide services for organizing the transport of goods by various modes of transport, as well as warehouse operators. The main criteria for evaluating the effectiveness of logistics according to the World Group Bank include:

- Customs - the effectiveness of customs and border clearance (speed, simplicity and predictability of formalities);
- Infrastructure - the quality of infrastructure related to trade and transport (for example, ports, railways, roads, information technology);
- International shipments - simplicity of organizing international shipments at competitive prices.
- Logistics quality and competence - the quality and competence of logistics services provided by market operators - logistics operators, transport companies, customs brokers, etc.
- Tracking and Tracing - tracking the passage of goods.
- Timeliness - timely delivery of goods.

The methodology for calculating the logistics performance index is not the only one. The Transport Intelligence Research Institute (UK) has developed the Emerging Market Logistics Index (EMLI), which reflects the attractiveness of the logistics market for foreign investment, as the Logistics Market Development Index for Emerging Economies. The dynamics of the logistics development index in countries with a developing economy for the period from 01.01.2013 to 01.01.2017,% is presented in Figure 4 is presented in Figure 4.

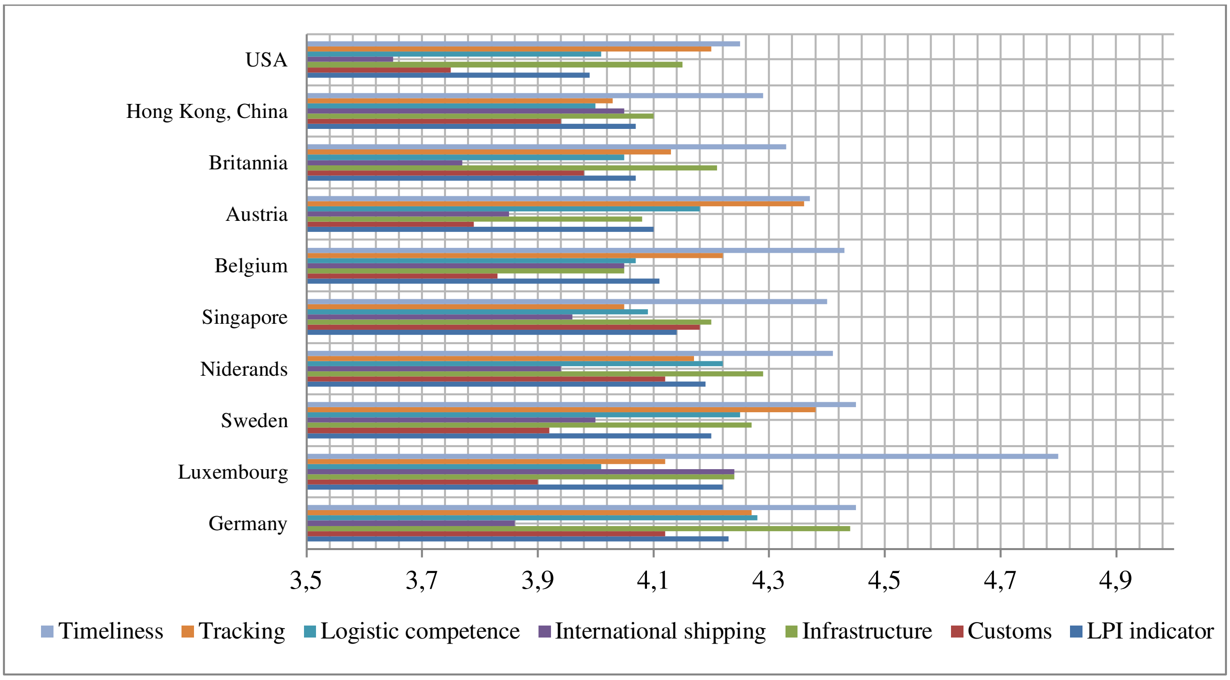

Figure 3 Rating of countries by gradation of the international logistics efficiency index as of 01.01.2017,%
Source: Developed by the author based on [29,30]

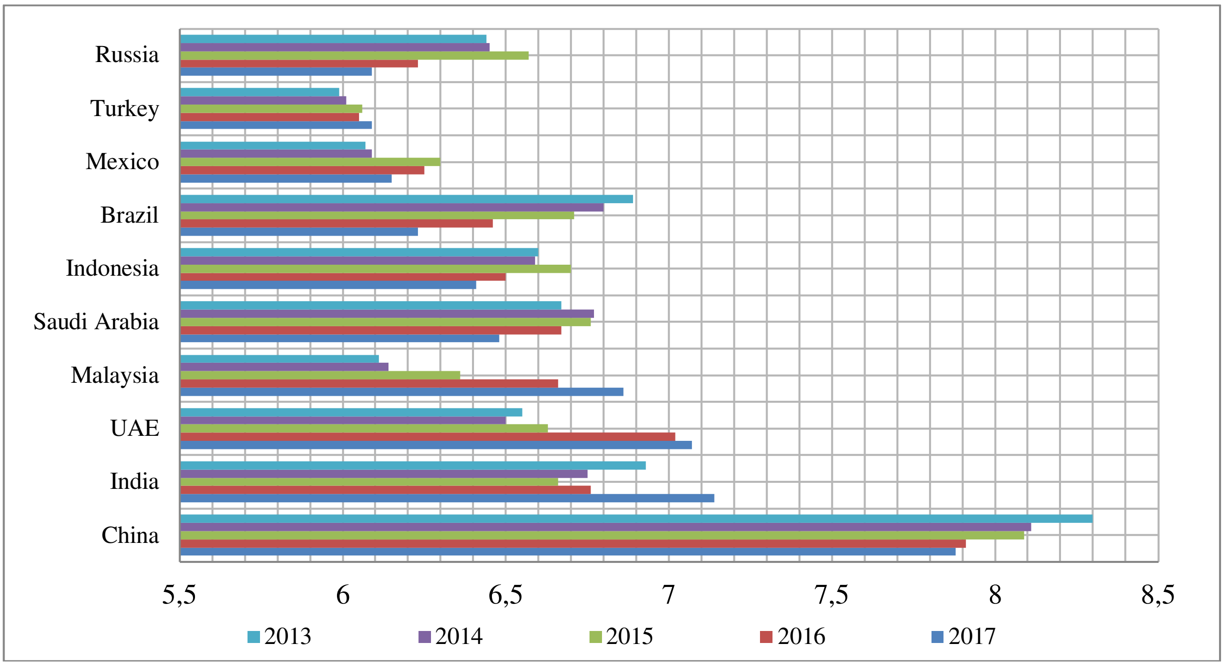

Figure 4 The dynamics of the logistics development index in countries with a developing economy for the period from 01.01.2013 to 01.01.2017,%
Source: Developed by the author based on [30]

According to the TOP-50 Rating of global logistics companies of 3PL-operators, the gross income of the 50 largest logistics companies in the world in 2016 amounted to $ 229.2 billion, which is 1.18% more than in 2015. From the perspective of the business as a whole, logistics exists to ensure that inventories arrive at the right time at the right place and with the right benefits at the lowest total cost. Reserves in themselves are of little value until they are placed there and then, where and when they are required to ensure the transfer of property from hand to hand or to create added value. If a company fails to constantly comply with this condition of place and time, it will have nothing to sell. In order for logistics to bring maximum strategic benefits, all of its functional links must work on the basis of integration. Success in each such link makes sense only if it contributes to the efficiency of the integrated logistics system as a whole. In fact, achieving the strategic goals of any business enterprise depends on the integration of logistics functions. The feasibility of the purpose of logistics depends on the successful implementation and coordination of specific functions related to physical distribution, production support and supply.

The second section of the chapter discusses the scheme of integration of logistics operations and the role that belongs to the management of inventory and information flows. At a large manufacturer, logistic operations sometimes consist of thousands of such movements, which ultimately come down to a single result: product delivery to one user, retailer, wholesaler, dealer or other consumer. At a major retailer, logistics covers a wide range of activities, from purchasing goods for resale to finding and attracting new customers and delivering purchases to customers. In an ordinary hospital, logistics begins with the supply of necessary resources, and ends with the full provision of surgical procedures and postoperative treatment of patients. The main thing is that in any business, regardless of size and type, logistics plays an important role and requires the continued attention of managers.

Integrated logistics allows you to most effectively realize the goals of business and the state. Profit maximization will be influenced by factors such as competitive position (positioning), competitive price, low costs and industry structure. Management is based on the method of involving individual interconnected elements in an integrated process (integrated logistics) in order to prevent irrational losses of material and other resources. Thus, logistics should be seen as an integrated process to ensure the creation of use value at the lowest cost. Until recently, the main success factor was considered exclusively market orientation. However, to ensure stable profitability, enterprises must choose and combine resources correctly. The concept of resource orientation in economically developed countries inevitably leads us to rethink the role of integrated logistics.

From this point of view, integrated logistics has the following features that have a direct impact on efficiency: the formation and use of key competencies, which involves a particularly effective combination of resources that competitors do not have; maintaining stable core competencies in the long-term strategic perspective; the ability of customers to benefit for themselves, the willingness to pay for additional services. An integrated logistics approach using a “value chain” is targeted at all participants. Value chains (supply chains) contain five areas of effectiveness: communication with suppliers; communication with consumers · technological processes within one unit; Logistic processes between departments within the enterprise; logistic ties between enterprises in the supply chain. The enterprise management system, which is built according to this type, is aimed at a significant reduction in costs by accelerating capital turnover, reducing lead times, and coordinating work with a network of suppliers. Thus, it should be noted that integrated logistics is a holistic process, which includes information and organizational support for the post-production stages of a product's life cycle: purchase, delivery, implementation, maintenance, including the supply of spare parts. The main goal is to constantly improve processes in all parts of the supply chain, reduce costs and maintain products and goods.

Logistic integration seems to be a multidimensional process of building logistics systems. This process takes place in different directions and not in the abstract market model of entrepreneurial activity, but in the space of specific economic ties. There is always an initiator of building such a system - a company in which, at the strategic level of management, logistics is perceived as a competitive development strategy. Only under this condition, the search for options for using the logistic approach in building a firm's strategy can begin. At the same time, the search begins for new forms of organizing relations with all subjects with which the company interacts in the value chain. When the logistics management goes beyond the boundaries of a specific legally and geographically separate company, the most difficult stage in the construction of a logistics system begins.

The rapid spread of this concept is hindered by fear of contacts with competitors and losses that can be incurred in the course of competition. However, it should be noted that the introduction of a new approach to managing an organization or expanding its activities is always crowned with an expansion in the scope of activity, income and the level of competitive position in the market. Gross income of key logistics operators in the world as of 01.01.2017 is presented in Figure 5.

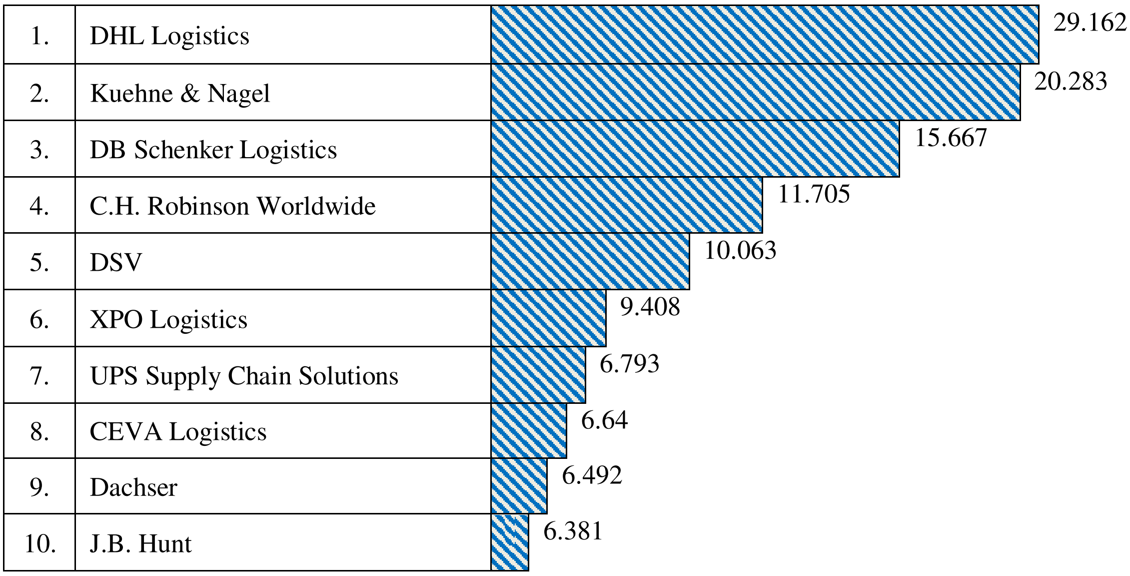

Figure 5. Gross income of key logistics operators in the world as of 01.01.2017 (billion dollars. USA)
Source: Developed by the author based on [30-32]

With the dynamics of key indicators of profitability of the key operational logistics market in the world as of 01.01.2017, DHL Logistics has become a leader in the provision of logistics services with a gross income of 29.162 billion. dollars. USA. With a global network in more than 220 countries, DHL is the most international company in the world and can satisfy a wide range of logistics services. Significant demand for logistics services from industrial and trading companies is an indicator of the intensity of the application of intercompany logistics integration. The competitive advantages of enterprises from the introduction of an integrated approach are achieved through: 1)increase the efficiency of the enterprise by reducing operating logistics costs and, as a result, reducing the cost of production; 2) increase the adaptation of the enterprise to constant changes in the environment; 3) risk reduction; 4) reducing the duration of operational and logistics cycles.

Logistics management is more often understood as a strategic parameter. Logistics is involved indirectly in the creation of value in the enterprise, but this is where the huge potential lies in the field of cost optimization, and therefore in the field of improving the profitability of all areas of the enterprise. Until now, the activities of individuals. Responsible for logistics in enterprises, focused on creating partnerships in the field of outsourcing. This trend exists today and will develop. This trend covers all areas of activity that can be well or very well performed by organizational units that are not part of the enterprise structure.

Service providers undertake more or less independent functions in accordance with their tasks or in accordance with their capabilities. However, the quality of logistics services and the costs of logistics as part of outsourcing do not always live up to expectations. As an alternative to discussion today, the concept of horizontal cooperation is proposed. It is a union of competitors, that is, a union of equal partners in the common market. This concept has many advantages over the concept of partnerships in the framework of outsourcing.

Logistic integration allows you to optimize the relationship between business entities, which increases the efficiency of each individual enterprise and the integrated system as a whole.

4 Conclusions

In modern business, logistics is the main tool that provides a holistic production process for the organization. Logistics is becoming a real organizational, technological and conceptual pillar of business entities and one of the most effective tools for the innovative development of enterprises in a developed market economy. It is taught that in the conditions of a volatile operating environment for companies and organizations, ensuring the efficiency of operations is a key guideline, the achievement of which is impossible without logistics. It has been established that logistics is a synthesis of many methods and principles of such traditional fields of activity as marketing, production, finance, freight transportation, it should also be noted that the use of logistics concepts allows for the tight integration of production, logistics, transport and information transfer on the movement of goods into a single system.

The key aspects of the organization of logistics in organizations in modern business conditions are substantiated, highlight the key stages and components of each type of logistics. The provisions considered regarding the unification of functional areas and their participants within the framework of a single logistics system, which suggests the need for an integrated approach in logistics. It is the development of information technologies, the introduction of new organizational forms - logistics networks, as well as the transformation of logistics organization forms that contribute to the integration of logistics processes.

The feasibility of combining logistics functions at the enterprise level is due to internal integration; integration across the entire supply chain - intercompany. At the same time, it should be pointed out that inter-company logistics integration allows for the rationalization (optimization) of logistics processes and operations; expanding the range of logistics services; increasing the number of customers for all integration partners; reduction of logistic risks; improving the quality of logistics services; strengthening the competitive position of logistics operators in the logistics services market. An in-depth analysis and critical study of the existing approaches to organizing the logistics of organizations in modern business conditions made it possible to determine at the global level the significant importance of logistics in the management system. The analysis and evaluation of the development of logistics services in the world in the context of leading logistics operations allowed us to state that there has been significant demand recently for logistics services from industrial and trading companies, which is an indicator of the intensity of the use of inter-company logistics integration in modern business conditions.

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THE IMPACT OF THE COVID-19 PANDEMIC ON SUPPLY CHAIN PERFORMANCE OF THE AUTO PARTS INDUSTRIES OF THAILAND

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Keywords: the COVID-19 pandemic**,** supply chain performance, automotive parts industries, Thailand
Abstract: This research aims to analyse the impact of the COVID-19 Pandemic on Supply Chain Performance of the Auto Parts Industries of Thailand. The primary data collected from an online questionnaire sent to 400 samples obtained by a stratified sampling method selected from tier 1, tier 2, and tier 3 auto parts manufacturers. The structural equation model applied for analysis. The results showed that the COVID-19 Pandemic, Environment performance, Negative performance, and operation performance affected supply chain performance. For suggestions from this research, first of all, the company's knowledge of internal management. And government involvement has a direct impact on the performance of the auto parts supply chain. The government's participation as factors of external influence also has an immediate effect on supply chain management. Company practices show that governments have played an essential role in promoting the auto parts industry's survival since its upstream. Midstream and downstream pressure has an indirect effect on corporate and consumer of supply chain management practices.

1 Introduction

The COVID-19 epidemic spread throughout the world has had a severe impact. To change the business environment, organizations across the globe need to adapt radically. By emphasizing the importance of being able to respond, adjust, and set up a crisis. Management mechanisms in a business environment are brimming with uncertainty due to severe limitations and blocking. Many urgent situations where gaining immediate attention; in the early stages of the epidemic, many companies began to shift towards in "recovery mode," companies have started planning long-term in difficult corporate recovery. In contrast, companies want to strengthen their operations and business flexibility. And risk management is more apparent than ever [1].

The COVID-19 Pandemic has affected the Thai automobile industry in various aspects, such as the cause of the economic recession both in Thailand and globally, which is a significant factor affecting automobile orders from both the domestic and export markets. It has resulted in the volume of automobile production in Thailand. This year to the lowest point in more than nine years, with the Kasikorn Research Center preliminary estimates from the perspective of the current epidemic situation that the quantity The production of automobiles in 2020 could shrink significantly by 21 to 25 percent, or produce just 1,520,000 to 1,590,000 cars, with this drop expected as a result of potentially much lower exports. It reached 750,000 to 780,000, shrinking 26 to 29 percent from 1,054,103 previously exported in 2019, while domestic sales are at risk of falling to 800,000 to 820,000 vehicles. 19 to 21 percent from 1,007,552 cars in the previous year and the auto industry's recovery to normal again is expected from mid-2021 to or early 2022 after the global economy will gradually recover in 2021 [2].

The global auto parts industry relies on manufacturing and supplies in China, Southeast Asia, and Thailand for low cost; however, in recent years, overall global developments have forced these companies to Rethink the supply chain and its stability and reliability for the uncertain future. It involved not only the COVID-19 Pandemic but also other external factors such as the trade war. Rules and regulations risk from natural disasters, including the environment or green logistics, etc.

For the above reasons, the researchers wanted to study and analyse the Impact of the COVID-19 Pandemic on Supply Chain Performance of the Automotive Parts Industries of Thailand.

2 Literature review

2.1 The COVID-19 Pandemic

The COVID-19 pandemic is an ongoing global pandemic of coronavirus disease 2019 (COVID-19). Caused by severe acute respiratory syndrome coronavirus 2 (SARS CoV 2). [3] The outbreak was identified in December 2019 in Wuhan, China. The World Health Organization declared the outbreak a Public Health Emergency of International Concern on 30 January 2020 and a pandemic on 11 March. [4]. As of 26 August 2020, more than 24 million cases of COVID-19 have reported in more than 188 countries and territories, resulting in more than 821,000 deaths; more than 15.6 million people have recovered [5].

The crisis has also highlighted the critical problem in the current model of manufacturing processes that are too dependent on a single production base. As a result, carmakers and parts manufacturers may consider modifying them for more flexibility in the future by diversifying risks in the acquisition of auto parts in the supply chain. The approach that expects vehicle manufacturers and parts manufacturers to adopt from now on may divide into two categories: reducing the Just in Time production system. At the same time, the other one focuses on reducing dependence on the base. It is a single production by shifting the production base to the country that is the region's strategic production base. The strategy is expected to lead to a more precise direction for the output of the supply chain, such as sharing platforms for each model of cars and parts, both within the same brand and between companies. And consolidating certain types of jobs in different tiers into the same company group especially, joining the same business segment as Tier 1 manufacturers, shortening the production supply chain [2].

2.2 Supply Chain Performance

Supply chain performance efficiency refers to supply chain activities that extend to meet end-customer needs, including product availability, on-time delivery, and inventory and all required production capacity in the supply chain. It responsively delivers performance, Supply chain efficiencies across corporate boundaries as they include base materials, components, sub-assemblies, and finished products, and distributed through multiple channels to end customers. It also crosses traditional corporate functions such as purchasing, manufacturing, distribution, marketing and sales, and research and development. It is victorious in a new environment; the supply chain needs constant improvement. To achieve this, we need performance measures, or "metrics," that support the advancement of global supply chain efficiency rather than company-specific or function-specific metrics. It impedes the improvement of the entire network. The component of supply chain efficiency assesses by environmental management performance. Positive economic performance Negative economic operation and operation performance [7]. Impact of the COVID-19 Pandemic severe impact on supply chain performance of auto parts supply chain. But be prepared to deal with it properly, in particular, supports domestic parts manufacturers to use more automation in their production processes. Environmental production concern Actions that enable cost reductions in the supply chain will increase the opportunity to compete with other production-based countries, especially with the expanding electric car industry.

2.3 Environment performance

Environment refers to centralized operations that accumulate expertise in each green activity, where each action has its specialized role in handling damaged returns and stock returns—the end of product life or the destruction of products (end of life). The discarded (discarded) products from downstream members of the supply chain [8]. Which are activities that involve the recycling and restoration of the product, and you another benefit, product chain activity, in this model, both forward logistics and reverse logistics, are considered part of the chain. Green supplies both upstream, midstream, and downstream activities are essential in building green logistics. However, all of these activities have to lead to the practice that goes into the green standard in three levels: First level, all departments, and activities in the supply chain have to move towards the green standard. The second level should create a collaborative network between departments in the organization to design greens to create a green supply chain across the organization. And the third level, expanding operations to production green and making the most of reverse logistics to achieve efficiency and effectiveness in the reverse mechanism. Environment performance is a factor affecting Supply Chain Performance [9,10].

2.4 Negative performance

Negative performance defines as the impact on the supply chain to create an increase in investment. Growth in investment, increasing operating costs increasing costs for purchasing environmentally friendly raw materials. Because of the negative economic performance because of this, it reduces market share and creates market opportunities [11]. The cynical interpretation reflects the increase in the cost of purchasing materials. It increased energy consumption waste materials and negative waste disposal agreement lower economic efficiency. It can see from the rise of the expenses associated with the investment. And the purchase of materials incompatible with the environment [12]. The delivery was not on time. Increasing inventory levels, increasing scrap rates, lack of promoting product quality. Growing product lines and inefficient use of capacity [13]. In terms of environmental performance, there have been many experimental studies. The lack of focus on supply chains [14].

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2.5 Operation performance

Operations performance in the supply chain performance is operations within the organization that impact the SCM guidelines on SCP. Govindan et al. [15] studied the relationship between SCM practices affecting supply chain performance in the automotive industry. The results of the research revealed "internal management support," "purchasing," and "internal management support". Also, the ISO 14001 certification" is an essential SCM practice, and factors affect the adoption and use of green supply. Some aspects factors in the handling of SCP in the electrical and electronic industries in Taiwan. It found that SCM's critical success factors were the division of activities into upstream, midstream, and downstream activities, which show outside. Environmental factors customer pressure regulatory pressure, government support, and environmental uncertainty. It is of the utmost importance to implement environmentally friendly practices as part of operations within the supply chain performance. The results of the literature review could create a conceptual framework for this research as follows:

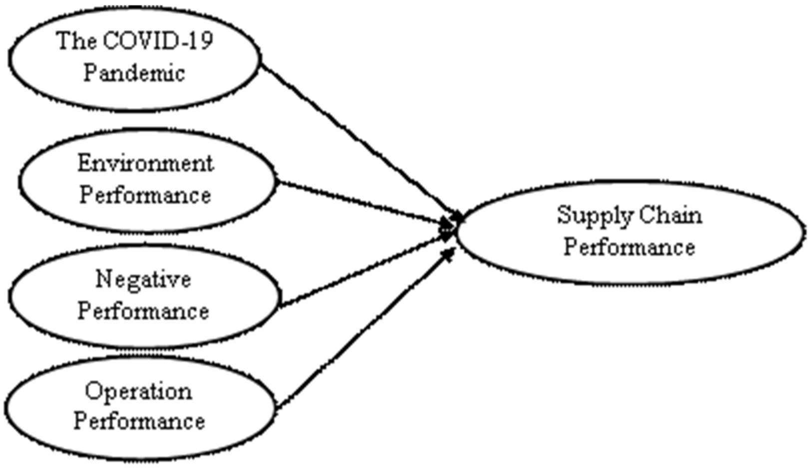

Figure 1 Research conceptual framework
Source: Updated from Aalirezaei et al. [7]; Zhu, Sarkis and Lai, [8]; Govindan et al. [15]

3 Research Methodology

Regarding the quantitative research method, the survey method applies by creating a questionnaire focusing on the design of research tools with suitable criteria for accurate measurement, possessing both validity and reliability in terms of content, approaches, and concepts. For this research, a questionnaire with validity and reliability according to the criteria and concepts constructed. The questionnaire survey was thoroughly designed under the advice of three academics experts. Before collecting the data, the questionnaire tested to determine what needs to be measured before issuing the survey and before receiving data, reliability testing applying Cronbach's Alpha test statistics to check whether their liability meets the criteria specified (Alpha value is lower than 0.60). If not, more questions added, and some may be cut and tested repeatedly until the questionnaire was accurate and reliable. Online surveys and postal questionnaires were sent directly to respondents from the sample's proportion randomized systematically—the values of the reliability coefficient of gauges used in this research. Cronbach's Alpha coefficient measuring the reliability or internal consistency of the meters gained the amount between .814 and .810; meanwhile, the 16 questions gained the Cronbach's coefficient at .822, expressing a high-reliability level.

Population and sample

The population is the auto parts industry in Thailand. Several car automotive assembler 18 companies, motorcycle automotive assembler eight companies, 1,700 companies in tier 2 and tier 3 auto parts manufacturer, and 709 companies tier 1 auto parts manufacturer [16]. The sample group stratified sampling from the auto parts industry in Thailand will be sampled. It is a group of automotive components Industrial groups of parts manufacturers, level 1 (tier 1), level 2, 3 (tier 2, 3), and sampling from industries with locations in each region (northern, central, eastern, western, and southern regions). Interviewed the manager of operations, logistics, and supply chain, a critical position that can provide excellent information and footprint on the auto parts industry's supply chain management. And complete as a junior executive and have a unique operational understanding. Method for selecting samples was based on probability principles (Non-Probability Sampling) by stratified sampling from the auto parts industries in Thailand; without any selection rules at 400.

4 Research Result

To answer the question of the research, the study and analysis of the impact of the COVID-19 Pandemic on supply chain performance of the autoparts industries of Thailand conducted. For exploratory factor analysis

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(EFA), the Common Factor Analysis, Principal Axis Factoring (PAF) method applied.

Table 1 Kaiser-Meyer-Olkin (KMO) and Barlett's Test of Sphericity

Kaiser-Meyer-Olkin (KMO)	0.781
Barlett's Test of Sphericity	
ApproximateChi-Square	317.579
df	194
Significant	.000

From Table 1: Kaiser-Meyer-Olkin (KMO) and Barlett's Test of Sphericity. KMO is 0.781 and Sig = .000 < 0.05, where 0 < KMO < 1 was close to 1, meaning all variables were related to factors using for further factor analysis. Common elements could explain the relationship between variables at a reasonable level [17].

Table 2 Statistical values for evaluating the structural validity of the empirical model

Index value	Benchmark	Statistical values obtained from analysis
p-value	Greater than or equal to 0.05	.081
χ^2 = 317.579 df.=194 χ^2/df. = 1.637	Should not exceed 2.0	1.637
CMIN/DF	Less than 2.0	1.637
GFI	More than 0.95	.951
TLI	More than 0.95	.962
AGFI	More than 0.95	.950
CFI	More than 0.95	.950
RMSEA	Less than 0.05	.050

From Table 2, the values χ^2= 317.579 df. =194, the values of χ^2/df. = 1.637, p-value = .081 and CMIN / DF = 1.637, which was less than 2.0, had a good level of consistency (Schumacker & Lomax, 2010), meaning that the structural equation model was in harmony with empirical data In addition, GFI = .951, TLI = .962, AGFI = .950 and CFI = .950 were greater than 0.95. All values showed a good level of consistency and found that RMSEA = .050 and PCLOSE or p-value = 0.000. The assumption was that RMSEA was less than 0.05 [18]. In conclusion, the index values check the consistency between the model and the empirical data was following the standard criteria and at a good level of conformity.

Table 3HOELTER

Model	HOELTER 0.5	HOELTER 0.1
Default model	215	218

From Table 3, the HOELTER 0.5 value was at 215, which was more than 200, indicating that the sample set in this study was well suited.

The Regression Weights showed regression coefficients. From the hypothesis testing of every correlation coefficient, all p-value = P = ***, which was less than 0.05 when studying all factor weight. It found that from the test of factor weight, every factor is non-zero, with every CR value greater than 1.96, and checking the statistic values from Table 2-3 together with the analysis of the factor weight. In conclusion, the model in figure 2 had been in harmony with empirical data at the significance level of 0.05, is shown in figure 2.

From the Figure 2. The confirmatory component analysis of the measurement model based on the Standardized Regression Weights showed that:

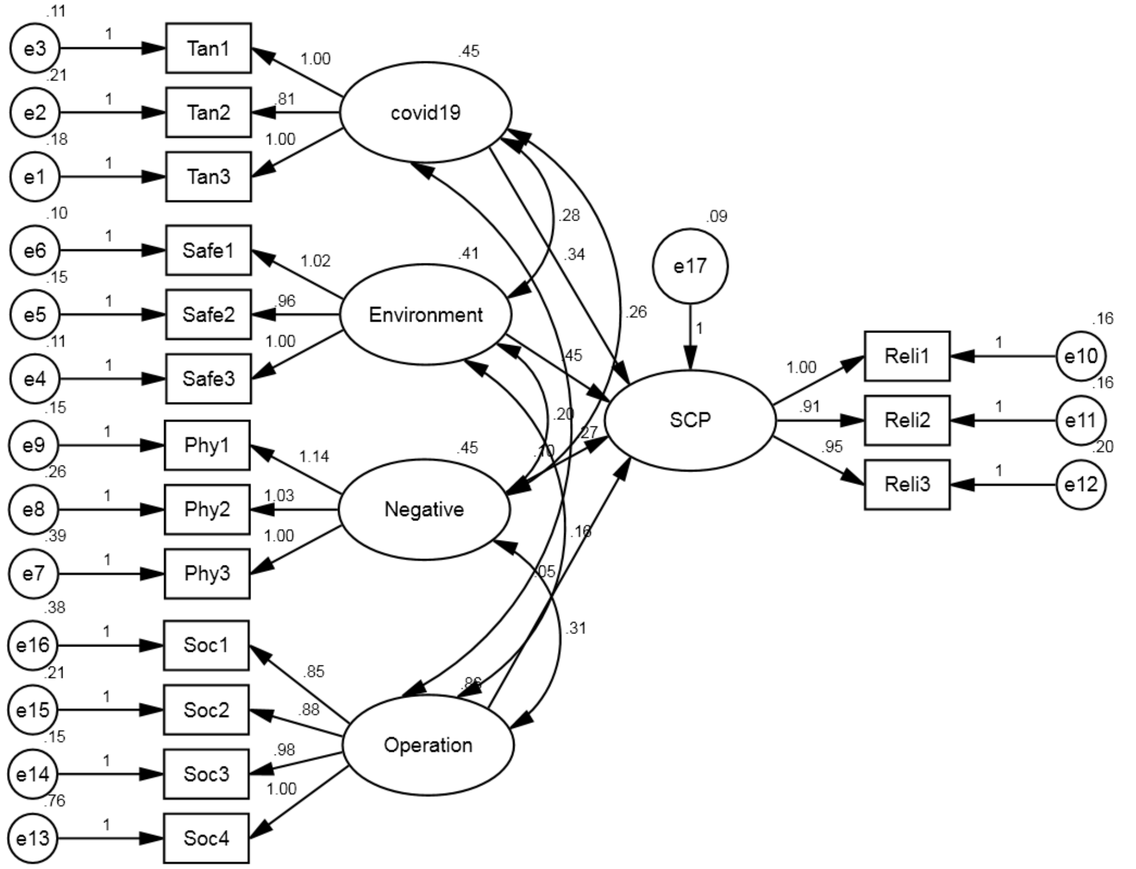
The weight of the standard factors in Figure 2 shows that the weighting factors included the COVID-19 Pandemic, Environment performance, Negative performance and operation performance. When considering from the highest to the lowest, Environment performance gained the most senior level at .37, followed by Negative performance (.47), the COVID-19 Pandemic (.37), and Operation performance (.27), simultaneously.

The weight of Environment performance of the variables could be observed in 3 levels from the highest to the lowest as follows: green activity (.90); green supplies (.88); green logistics (.84).

The weight of Negative performance of the variables could be observed in 3 ranks from the highest to the lowest as follows: reduce market share (.89); increase cost (.81); increase energy (.73)

The weight of the COVID-19 Pandemic of 3 observable variables could be ranked from the highest to the lowest as follows ongoing global pandemic (.89); reduction of the just-in-time (.85); diversifying risk (.76)

The weight of Operation performance of the variables can be observed in 4 numbers from the highest to the lowest as follows: the possibility of internal management support (.92); relation between SCM (.87); operation within organization (.79); environment uncertainly (.73).



χ^2= 317.579 df. = 194 , χ^2/df. = 1.637, p-value = .081, CMIN / DF = 1.637, GFI = .951, TLI = .962, AGFI = .950, CFI = .950, RMSEA = .050, at significant level .05

Figure 2. The structural equation model of The Impact of the COVID -19 Pandemic on Supply Chain Performance of the Auto Parts Industries of Thailand

Table 4 Test results for the path coefficient of The Impact of the COVID-19 Pandemic on Supply Chain Performance of the Auto Parts Industries of Thailand. And checking the consistency of the model and the empirical data

Cause variable	Effect variable	Estimate	S.E.	Z-test	p	R^2
X1 = The COVID-19 Pandemic	Y = Supply Chain Performance	.342	.055	6.199	.000	.75
X2 = Environment performance		.448	.051	8.771	.000	
X3 = Negative performance		.099	.047	2.100	.036	
X4 =Operation performance		.051	.029	1.776	.050	

From the Table 4. The effects of checking the consistency of the model and the empirical data developed were inharmonious with the data. The conclusion of the coefficient testing of the structure equation model found that:

The weighting factors included the COVID-19 Pandemic, Environment performance and Negative performance and Operation performance. When considering from the highest to the lowest, Environment performance gained the most senior level at .37, followed by Negative performance (.47), The COVID-19 Pandemic (.37), and Operation performance (.27), simultaneously.

When considering the R2 value from Table 4, it found that the COVID-19 Pandemic, Environment performance, Negative performance and Operation performance could predict Supply Chain Performance at 75%.

When considering the harmonization and empirical data, it found that the ratio between R2 and the degrees of freedom was 1.637, which was less than 2; the index of harmony (CFI) was .951, which was higher than 0.95 indexes. The suitability measurement (TLI) was .962, which was higher than 0.95. The revised Harmony Index (AGFI) was .950, which was higher than .95, and the Estimation Index of Estimates parameter value (RMSEA) was .050, which was less than 0.05 (Wanichbuncha, 2013).

Therefore, it could conclude that The Impact of the COVID-19 Epidemic on Supply Chain Performance of the Auto Parts Industries of Thailand was consistent with the empirical data.

5 Discussion and Findings

The COVID-19 Pandemic is the ongoing global pandemic of the 2019 coronavirus (COVID-19). The crisis highlights a critical issue in the manufacturing process model in the auto parts supply chain severely. It is to aggravate the auto parts industries' situation in recent times, which has faced an economic slump around the world. However, factors affecting the supply chain are that the Thai auto parts industry relies too much on a manufacturing base in China, a vast production base. As a result, automakers and parts manufacturers may consider future flexibility modifications by diversifying the risk of purchasing auto parts in the supply chain. The approach that automakers and parts manufacturers expected to adopt from now on could divide into two categories: just-in-time production cuts. Simultaneously, the other focused on reducing dependency on bases—single production by relocating production base to the country of the regional strategic manufacturing base.

The strategy is expected to lead to a more precise direction for supply chain manufacturing, such as sharing platforms for individual cars and parts, both within the same brand and between companies and the inclusion of certain types of work in different tiers. The same group of companies, especially joining the same business as 1 tier manufacturers, shortened their production supply chains. Also, supply chain performance factors that expand to meet end-customer needs include product availability, on-time delivery, and all required inventory and capacity in the supply chain. To deliver performance in a way that meets supply chain performance across the enterprise's boundaries as it includes base materials, components, sub-assemblies, and finished products and is distributed across multiple channels to end customers. It also crosses traditional corporate functions such as purchasing, manufacturing, distribution, marketing and sales, and research and development. It is victorious in a new environment; the supply chain needs constant improvement.

The negative economic performance is consistent with Aalirezaie et al. [7] research, together with the impact factors of the COVID-19 Pandemic severely affecting the auto parts industry in supply chain performance. Environmental performance factors are green manufacturing activities, damaged return management, stock returns, product returns, product expiration, or product destruction. The end of life and discarded product from downstream members of the supply chain, in line with Schmacker & Lomax [19] research activities related to product recycling and restoration. And another benefit, the product chain activities in this model, both forward and reverse logistics, are factors that affect the supply chain of the auto parts industry in the world. Thailand. It is consistent with the Sarkis study [8]. Environmental supply chain management, both upstream, midstream, and downstream activities are essential in building green logistics. However, all of these activities must lead to green practice at three levels: first level, all departments, and activities in the supply chain must move towards a green standard. The second level should create a collaborative network between departments within the organization to design greens to create a supply chain across the organization. And the third level extends operations to production and makes the most of reverse logistics to achieve efficiency and effectiveness in the traction mechanism. Environmental efficiency is a factor that affects supply chain performance. This research is consistent with Nylund, [9]; Zhan and Liu [10].

6 Concluding remarks

The impact of the COVID-19 Pandemic on the company's internal performance, negative from the decline in production capacity and sales. Environmentally friendly production factors Economic globalization ecological issues and corporate social responsibility. These factors affect the performance of the auto parts supply chain. For suggestions from this research, first of all, the company's knowledge of internal management. And government involvement has a direct impact on the performance of the auto parts supply chain. The government's participation as factors of external influence also has an immediate effect on supply chain management. Company practices show that governments have played an essential role in promoting the auto parts industry's survival since its upstream. Midstream and downstream pressure has an indirect effect on corporate and consumer of supply chain management practices. Government involvement factors have a significant impact on the industry. By policy measures on tax deductions. Its suspension of payments by banks to sustain internal operations. Compensation to employees when the government has announced that the company will stop working and work from home. The issuance of subsidy policy to support organizations in operating their supply chain during the time the company confronts the COVID-19 Pandemic. It affects the operations within the company and the auto parts industry as a whole.

7 The future direction of research

Future research should study the impact of the COVID-19 epidemic on delivering value to customers in the auto parts supply chain, and supply chain risk management of the auto parts industry in Thailand.

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INFLUENCE OF TWO DIFFERENT ACCURACY IMPROVEMENTS TO NUMERICAL PRICE FORECASTING

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Keywords: price forecasting, numerical modelling, exponential approximation, commodity exchange
Abstract: The paper aims to compare two different strategies of accuracy improvement of studied prognostic numerical models. The price prognoses of aluminium on the London Metal Exchange were determined as the numerical solution of the Cauchy initial problem for the 1st order ordinary differential equation. To make the numerical model more accurate two ideas were realized, the modification of the initial condition value by the nearest stock exchange (initial condition drift) and different way of creation of the differential equation in solved Cauchy initial problem (using two known initial values). With regard to the accuracy of the determined numerical models, the model using two known initial values obtained slightly better forecasting results. The mean absolute percentage error of all observed forecasting terms was mostly less than 5%. This strategy was more successful in problematic price movements, especially at steep price increase and within significant changes in the price movements. Larger fluctuation of prognoses calculated by this model was disadvantageous in forecasting terms with a small error. Moderate increase of prognoses obtained by the model using initial condition drift better described price fluctuation. Both chosen strategies eliminated the forecasting terms with the mean absolute percentage error larger than 10%. Therefore, we recommend both strategies as acceptable way for commodity price forecasting.

1 Introduction

Forecasting the prices of metals is important in many aspects of economics. Non-ferrous metals are indispensable industrial material and strategic supports of national economic development. Therefore, the price forecasting of metals is critical for researchers. The forecast on commodity prices usually takes into account predictive mathematical models [1-23]. There are a lot of different approaches to forecasting and improvements of specific forecasting algorithms. Statistical models usually based on time series analysis are often used [4,7,10,20-22]. Recently statistical models with multi-objective programming for non-linear time series [18], different strategies for automatic lag selection in time series analysis [5] and functional time series analysis [2,8] are mostly proposed. There are a lot of novel hybrid methods to forecast commodity prices consisting of the classical GARCH model and neutral network model to boost the prediction performance [9]. The analytic network process is one of the multi-criteria decision-making methods widely used to solve various issues in the real world of financial management [1,3,11,23]. The method for time series analysis are also combined by adding stochastic term to the first-order differential equation. Solution of this equation represents the time response function which is capable of creating evolving path of the commodity price [6]. Deep learning models and a new intelligent system, namely group method of data handling are quickly developing for prediction of commodity prices [3,17,19].

Our prognostic models are based on numerical modelling using numerical solution of the Cauchy initial problem for the 1st order ordinary differential equations [12-16]. Observed numerical models used publicly available aluminium prices on the London Metal Exchange (LME) [24] collected from December 2002 to June 2006. The monthly averages of the daily closing aluminium prices "Cash Seller&Settlement price" (in US dollars per tonne) were worked on, see Figure 1.

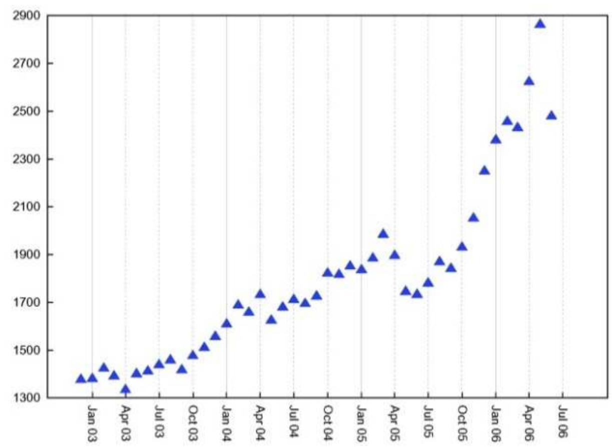

Figure 1 Course of the aluminium prices on LME in the years 2003 – 2006 [13-16]

2 Mathematical models

In previous papers [13-17] we interested in finding improvements of created numerical models. Based on obtained results, the most accurate prognostic models were selected. In both models, the model using initial condition drift and the model using two known initial values, the Cauchy initial problem in the form

$$y' = a_1 y, \quad y(x_0) = y_0 \tag{1}$$

was considered. The particular solution of the problem (1) is in the form $y = k\, e^{a_1 x}$, where $k = y_0\, e^{-a_1 x_0}$.

The exponential trend was chosen according to the test criterion of the time series' trend suitability. The values $\ln(Y_{i+1}) - \ln(Y_i)$, for $i = 0, 1, ..., 42$, have approximately constant course, where Y_i was the aluminium price (stock exchange) on LME in the month x_i.

In the model using initial condition drift the coefficient a_1 was obtained by approximating the prices of the approximation term by the least square's method. Let us consider two different ways of the approximation terms' creation, variant B and variant E, [13-16], see Figure 2 and Figure 3.

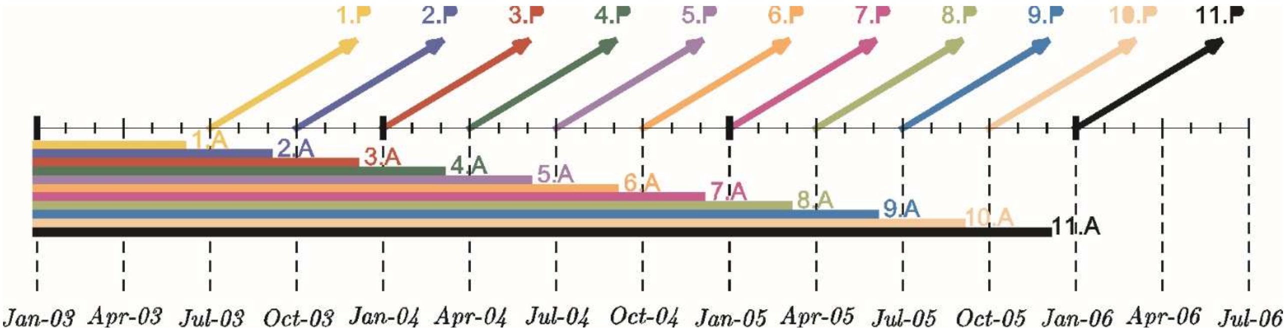

Figure 2 Variant B (A – approximation term, P – forecasting term)

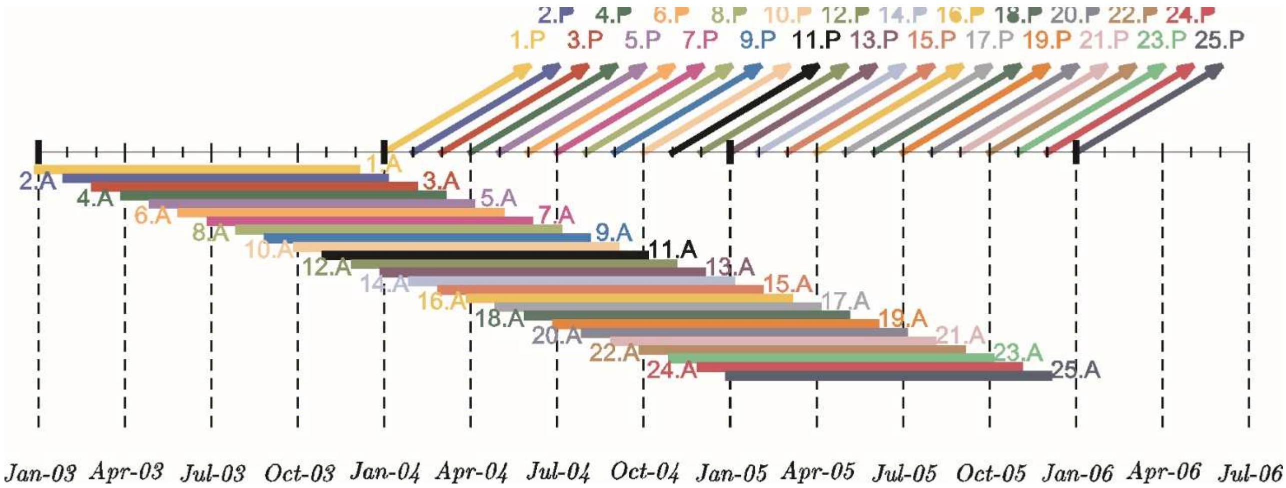

Figure 3 Variant E (A – approximation term, P – forecasting term)

According to the acquired approximation function $\tilde{y} = a_0 e^{a_1 x}$, the Cauchy initial problem (1) was written in the model using initial condition drift in the form

$$y' = a_1 y, \quad y(x_i) = Y_i, \tag{2}$$

where $x_i = i$ was the last month of the approximation term, Y_i was the stock exchange in the month x_i.

In the model using two known initial values, two known points $[x_{i-1}, Y_{i-1}]$ and $[x_i, Y_i]$ were considered, where x_{i-1}, x_i were the orders of the month and Y_{i-1}, Y_i were stock exchanges in the months x_{i-1}, x_i. That means $[x_i, Y_i]$ were the values corresponding to the next month in comparison with those of $[x_{i-1}, Y_{i-1}]$. Substituing points $[x_{i-1}, Y_{i-1}]$, $[x_i, Y_i]$ to the general solution of the problem (2) we acquired $Y_i = Y_{i-1} e^{a_1(x_i - x_{i-1})}$.

After some manipulation the formula of unknown coefficient a_1 was determined

$$a_1 = \frac{1}{x_i - x_{i-1}} \ln\left(\frac{Y_i}{Y_{i-1}}\right).$$

Substituting a_1 to the Cauchy initial problem (2) we obtained

$$y' = \frac{1}{x_i - x_{i-1}} \ln\left(\frac{Y_i}{Y_{i-1}}\right) y, \quad y(x_i) = Y_i. \tag{3}$$

for $i = 1, 2, 3, ...$

The unknown values of aluminium prices were computed by the numerical solution of the Cauchy initial problems (2) and (3) by means of the numerical method [25]. The method used the following numerical formulae

$$x_{i+1} = x_i + h,$$

$$y_{i+1} = y_i + bh + Qe^{v x_i}\left(e^{vh} - 1\right),$$

for $i = 1, 2, 3, \dots$, where $h = x_{i+1} - x_i$ was the constant size step. The unknown coefficients were calculated by means of these formulae $v = \frac{f''(x_i, y_i)}{f'(x_i, y_i)}$, $Q = \frac{f'(x_i, y_i) - f''(x_i, y_i)}{(1-v)\, v^2 e^{v x_i}}$, $b = f(x_i, y_i) - \frac{f'(x_i, y_i)}{v}$.

In both determined models daily forecasting was used. The interval $\langle x_i, x_{i+1} \rangle$ of the length $h = 1$ month was divided into n parts, where n is the number of trading days on LME in the month x_{i+1}. We gained the sequence of the division points $x_{i0} = x_i$, $x_{ij} = x_i + \frac{h}{n} j$, for $j = 1, 2, \dots, n$, where $x_{in} = x_{i+1}$. For each point of the subdivision of the interval, the Cauchy initial problem in the form (2) or (3) was solved. By calculating the arithmetic mean of obtained daily prognoses, the monthly prognosis of the stock exchange in the month x_{i+1} was obtained. Thus, $y_{i+1} = \frac{\sum_{j=1}^{n} y_{ij}}{n}$. Daily forecasting corresponds to creation of the monthly averages of daily closing aluminium prices on LME.

In the model using two known initial values by means of two known points $[x_{i-1}, Y_{i-1}]$ and $[x_i, Y_i]$ the prognosis y_{i+1} in the month x_{i+1}, $i = 1, 2, 3, \dots$, was calculated. In this way price prognoses in the months from February 2003 to June 2006 were gradually determined. In the model using initial condition drift the prognoses within six months following the end of the approximation term were forecasted. The accuracy of the model was improved by changing initial condition value y_{i+s}, $s = 1, 2, \dots, 5$ by the stock exchange Y_{i+s-1}, if the absolute percentage prognosis error in the month x_{i+s} exceeded chosen value 7%. Otherwise, the initial condition value in the month x_{i+s} was replaced by calculated monthly prognoses y_{i+s} [13-16].

To compare the forecast accuracy in different forecasting terms of the length six months, the mean absolute percentage error (MAPE) $\bar{p} = \frac{\sum_{s=1}^{t} |p_s|}{t}$ was determined [13-16]. Let consider the absolute percentage error $|p_s| = \frac{|y_s - Y_s|}{Y_s} .100\,\%$, which told us how close the calculated prognosis was y_s in the month x_s to the real stock exchange Y_s. The price prognosis y_s is acceptable in practice, if $|p_s| < 10\,\%$. Otherwise, it is called critical forecasting value [12-16].

3 Results and discussion

3.1 Results of determined numerical commodity price forecasting

In previous research we dealt with improvement of the created numerical models by increasing their forecasting accuracy. The first way of improvement, used in the model using initial condition drift, was based on changing the value of the initial condition in solved Cauchy initial problem. The most accurate were the models in which the stock exchange was used as a value of the initial condition. Observing different ways of changing the initial condition value, we have found out that replacing the initial condition value by the stock exchange, which was the nearest to month where the initial condition drift was occurred, was the most successful. That allowed to put calculated prognoses closer to the real stock exchanges and significantly improved forecasting results [13-16].

Another way of improvement of the forecasting process, used in the model using two known initial values, was trying to find different way of creating of the differential equation in the form $y' = a_1 y$. The coefficient a_1 in the Cauchy initial problem calculating prognosis in the month x_{i+1}, was determined by using two known points $[x_{i-1}, Y_{i-1}]$ and $[x_i, Y_i]$, where Y_{i-1} and Y_i were known stock exchanges in previous months x_{i-1} and x_i. Comparing the values of prognoses obtained by the model with real stock exchanges, we have found out that predictions of this model were also satisfactory [12].

Within studied group of 36 forecasting terms of variants B and E, see Figure 2 and Figure 3, the success of the determined models was studied. In both observed models, the MAPE and number of critical values were determined for each forecasting term. Obtained results are shown in Figure 4 and Figure 5.

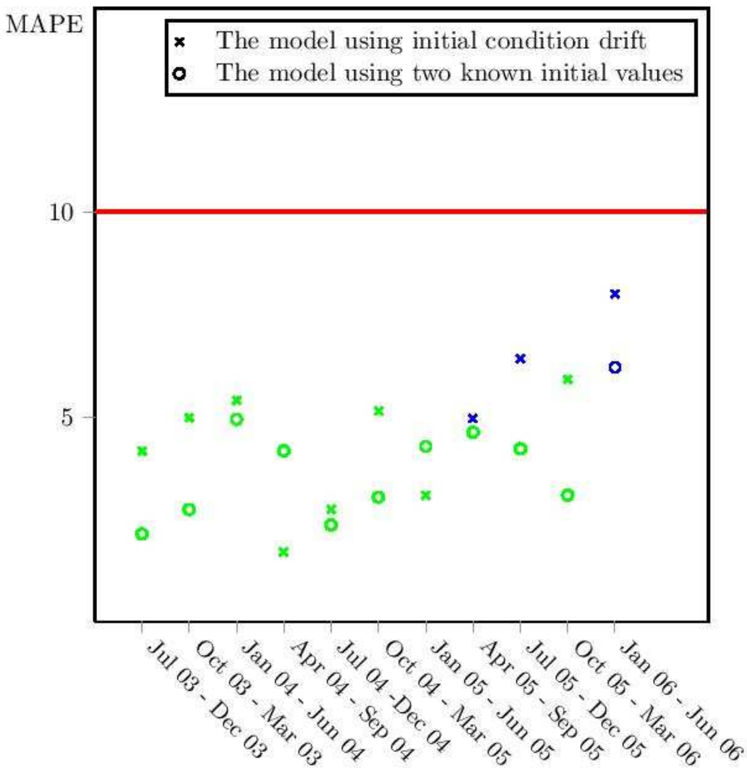

Figure 4 The mean absolute percentage errors for chosen mathematical models - variant B.

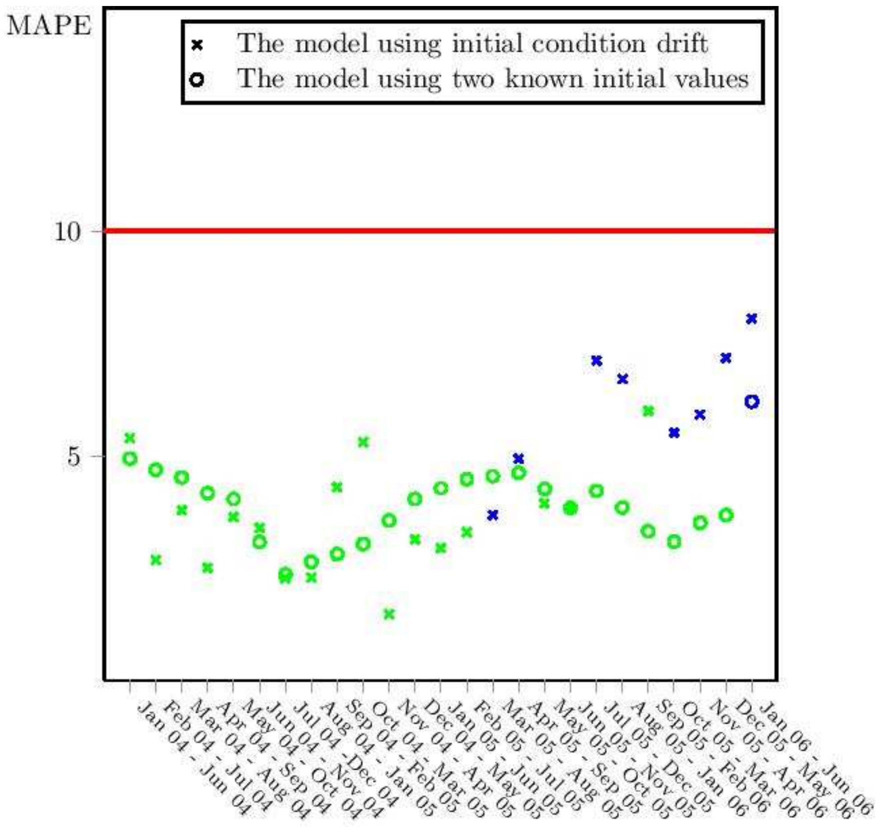

Figure 5 The mean absolute percentage errors for chosen mathematical models - variant E.

In order to compare forecasting results in both variants B and E, the arithmetic mean of MAPEs was determined. We also dealt with specifying the most accurate model for each forecasting term. The forecasting success of determined mathematical models within the forecasting terms is visible in Table 1 and Table 2.

Table 1 The success rate of determined mathematical models - variant B.

Criterion	The model using initial condition drift	The model using two known initial values
The arithmetic mean of MAPE	4.77%	4.00%
The number of the most accurate price prognoses	2	9
The number of the critical values	4	1
The number of MAPE at least 10%	0	0

Table 2 The success rate of determined mathematical models - variant E.

Criterion	The model using initial condition drift	The model using two known initial values
The arithmetic mean of MAPE	4.37%	3.91%
The number of the most accurate price prognoses	13	13
The number of the critical values	9	1
The number of MAPE at least 10%	0	0

The tables show the model using two known initial values slightly more accurate. This model, in both variants B and E, acquired lower arithmetic mean of MAPEs of all forecasting terms. In variant B, containing 11 forecasting terms, the model was more successful than the model using initial condition drift 9 times. Considering variant E, in which 25 forecasting terms were observed, success of both numerical models was identical. Both models obtained better results in comparison to the other 13 times. In one forecasting term the same results in both models were gained.

The forecasting success of the model using two known initial values was also indicated by lower number of critical values. These values pointed at the months and price movements in which forecasting failed. By the model using two known initial values, there was only one prognosis, in both variants B and E, with absolute percentage error exceeded 10%. It was prognosis in June 2006, when aluminium price steeply increased, so forecasting could not follow it. Prognoses calculated by the model using initial condition drift obtained absolute percentage error at least 10% in variant B four times and in variant E nine times. The cause of forecasting fail was the rapid significant change in the price course. Within these months occurred either rapid price decrease after price increase (1 critical value in variant B and 2 critical values in variant E) or rapid price increase after price decline (3 critical values in variant B and 7 critical values in variant E). The larger were changes, the higher errors of the prognoses were gained. In both considered models there was no forecasting term, where the mean absolute percentage error exceeded 10%. This parameter pointed at periods and price movements in which forecasting was unacceptable.

Better forecasting results of the model using two known initial values were also confirmed by the distribution number of the forecasting terms according to their mean absolute percentage error, see Table 3 and Table 4.

Table 3 Distribution of the number of the forecasting terms according to their MAPE - variant B.

MAPE	The model using initial condition drift	The model using two known initial values
< 5%	6	10
⟨5%, 7,5%)	4	1
⟨7,5%, 10%)	1	0
≥ 10%	0	0

Table 4 Distribution of the number of the forecasting terms according to their MAPE - variant E.

MAPE	The model using initial condition drift	The model using two known initial values
< 5%	16	24
⟨5%, 7,5%)	8	1
⟨7,5%, 10%)	1	0
≥ 10%	0	0

Tables clearly show, that by means of the model using two known initial values more forecasting terms with lower MAPE were acquired than by the model using initial condition drift. All forecasting terms calculated by the model using two known initial values acquired MAPE less than 7.5%. Mostly the mean absolute percentage error was less than 5%, 10 forecasting terms in variant B and 24 forecasting terms in variant E. There was just one forecasting term with MAPE in the interval ⟨5%, 7.5%), the forecasting term *January 2006 – June 2006* with MAPE 6.21% in both variants B and E. Within this forecasting term aluminium prices were steeply fluctuating.

Consider the model using initial condition drift, there were less forecasting terms in intervals with lower MAPE. The most accurate forecasting, with MAPE less than 5%, was obtained in 6 forecasting terms of variant B and in 16 forecasting terms in variant E. Higher forecasting inaccuracies, MAPE from interval $\langle 5\%, 7.5\%)$, occurred also quite often, in 4 forecasting terms in variant B and in 8 forecasting terms in variant E. The least accurate was forecasting also in the forecasting term *January 2006 – June 2006,* with MAPE 8.00% in variant B and 8.06% in variant E.

Let us observe the forecasting success of the determined numerical models by means of distribution of the number of the forecasting terms with different error rate. Based on the prognosis accuracy analysis of models, the forecasting terms were classified into three classes [13,15]. In trouble free forecasting terms forecasting was the most accurate due to the fact that no critical value was obtained in these terms. In the second group there were forecasting terms with a small error, in which some critical value was acquired by forecasting, but MAPE of the forecasting term was less than 10%. Forecasting failed in forecasting terms with a big error, where MAPE was at least 10%. Distribution of number of the forecasting terms in these determined groups, in both variant B and E, is shown in Table 5 and Table 6. In Figure 4 and Figure 5 trouble free forecasting terms are green, forecasting terms with a small error are blue and forecasting terms with a big error are red.

Table 5 Distribution of the number of the forecasting terms in determined groups - variant B.

Type of forecasting term	The model using initial condition drift	The model using two known initial values
Trouble free forecasting terms	8	10
Forecasting terms with a small error	3	1
Forecasting terms with a big error	0	0

Table 6 Distribution of the number of the forecasting terms in determined groups - variant E.

Type of forecasting term	The model using initial condition drift	The model using two known initial values
Trouble free forecasting terms	17	24
Forecasting terms with a small error	8	1
Forecasting terms with a big error	0	0

Forecasting by means of both models was so accurate that there were no forecasting term with a big error. That fact pointed at suitable forecasting accuracy within complicated price movements. The problematic forecasting, which appeared in forecasting term with a small error, was observed just in one forecasting term using forecasting by two known initial values in both variant B and variant E. If prognoses were calculated by the model using initial condition drift, there were 3 forecasting terms in variant B and 8 forecasting terms in variant E with a small error. Mostly forecasting by means of both determined models was so accurate that all calculated prognoses were less than 10%.

3.2 Discussion about the success of observed numerical models

Let analyse the forecasting success of determined numerical models. Comparing the prognoses of both types of forecasting and stock exchanges within observed periods we have found out different strategies of the forecasting errors' correction. In the model using initial condition drift the stock exchanges in approximation term were approximated by the least square's method. In variant B longer approximation terms than in variant E were used. Obtained exponential approximation function $\tilde{y} = a_0 e^{a_1 x}$ determined differential equation in the form $y' = a_1 y$, which affected rate of an increase or a decrease of calculated prognoses. Usually, the approximation terms with a price increase belonged to the observed forecasting terms. Therefore, calculated prognoses were increasing too. Using longer approximation terms, a prognoses increase was more moderate, so forecasting did not react so strongly to fluctuation in the price evolution. On contrary, forecasting in variant E was based on shorter approximation terms. Therefore, calculated prognoses increased or decreased steeper and forecasting responded to changes in the price source. Within the most problematic forecasting terms a steep price increase and changes in price movements usually occurred. The forecasting errors in the model using initial condition drift were so high, that the initial condition drift was necessary for an approach to the real stock exchanges. After initial condition drift the next calculated prognoses were immediately put closer to the values of the stock exchanges, what significantly improved forecasting. But approaching to real stock exchanges was gradual and slower in comparison to forecasting by the model using two known initial value.

Forecasting by the model using two known initial value was usually more advantageous due to different strategy of forecasting. The computed prognosis kept the trend of two previous initial stock exchanges in the months x_{i-1} and x_i. It means, these relations hold $Y_{i-1} < Y_i < y_{i+1}$, $Y_{i-1} > Y_i > y_{i+1}$, respectively. The success of the forecasting by this model depended on the intensity of either an increase or a decrease in three observed months x_{i-1}, x_i and x_{i+1}. The steeper increase or decrease in the price course was occurred, that means inequality $|Y_{i+1} - Y_i| > |Y_i - Y_{i-1}|$ was larger, the more successful was forecasting by the model using two known initial value. The calculated prognoses immediately approach steep price increase and also changes in the price course.

Within forecasting terms with a small error moderate fluctuation often appeared. Moderate changes in the price course caused larger fluctuation of the prognoses calculated by the model using two known initial value. Otherwise, within moderate fluctuation the absolute prognoses errors were smaller, so the initial condition drift did not occur in the model using initial condition drift. An increase of calculated prognoses was moderate and better described price fluctuation. Therefore, moderate forecasting by the model using initial condition drift became usually more accurate within moderate fluctuation.

4 Conclusions

The main purpose of this paper was comparing the performance of two successful alternative strategies of commodity price forecasting. The findings of this research work are in line of previous studies. Both models were created as improvements of our less accurate prognostic numerical models. Their forecasting success was indicated by reducing unacceptable forecasting results. Using these forecasting strategies, no forecasting term with MAPE larger than 10% was acquired. Although, the analysis indicated similar forecasting results, observed parameters were slightly better for the model using two known initial values. The arithmetic mean of MAPE and number of critical values were lower than in the model using initial condition drift. There were also more forecasting terms with lower MAPE.

Comparing the values of prognoses obtained by determined models, we have found out that prognoses determined by the model using two known initial values were more often changing than prognoses of the model using initial condition drift. Therefore, the strategy of using two known initial value was more suitable within problematic price movements, which caused higher forecasting errors. We recommend using this model especially at steep price movements and significant changes in the price course. If the price course was moderate, gradually changing prognoses of the model using initial condition drift obtained lower prognoses errors.

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DESIGN OF WASTE VEGETABLE OIL COLLECTION NETWORKS APPLYING VEHICLE ROUTING PROBLEM AND SIMULTANEOUS PICKUP AND DELIVERY

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Keywords: Vehicle Routing Problem Simultaneous Pickup and Delivery - VRPSPD, waste vegetable oil, recovery logistics
Abstract: The growth of industrialization in Mexico has caused an increase in the demand for materials to satisfy the consumption of goods and services of a growing population. Given this scenario, there is a rise of the residual generation with affectations on the ecosystem and population health. Hence, the objective of this research was to design a network for waste vegetable oil collection based on vehicle routing problem with simultaneous pickup and delivery, starting from a distribution centre to 49 restaurants, as the generation sources of waste vegetable oil. The Vehicle Routing Problem Simultaneous Pickup and Delivery with Time Windows was the variant used as a vehicle routing method to solve the problem. The free software VPRPD was the tool used to solve the vehicle routing problem with simultaneous pickup and delivery that allowed to specify time restrictions. This software uses the simulated annealing metaheuristics in its syntax. As a result, it was obtained a total of 8 networks, for a vehicle capacity utilization of 70 percent in the 6 *t* vehicle and 46 percent in the 8 *t* vehicle.

1 Introduction

The growth for industrialization in Mexico has caused an increase in the demand of materials to satisfy the consumption of goods and services of a growing population. Given this scenario, the increase in residual generation at the national level is evident, with affectations on the ecosystem and population health. Therefore, it is everyone's responsibility to find solutions that help mitigate these damages [1]. Scientific and technical advances have made it possible to identify that many of these wastes can be a potential feedstock in several production processes [2-5].

An example of this waste generation is the vegetable oil supply chain, where the last user generates waste vegetable oil (WVO), a residue obtained from frying food. This waste is recovered when it is subjected to a physical treatment process, becoming a good enough material that can be used in the production systems of the chemical industry for the production of biofuel as well as a food supplement for the livestock sector. The commercial value of the waste vegetable oil is evident, therefore, it is necessary to design logistic networks that transport the residual from the generation sources to a collection centre, where it can be treated and valorised. It would not only have a positive environmental and social impact; it would also open up new business opportunities with sustainable competitive advantages.

Residual management and products recovery are a complex problem that requires planning, management and, control of the flow of materials and products [6]. Hence, the recovery logistics process has a fundamental role, which requires the design, development, and control of a system to collect the out-of-use product, and logistics management must be supported by strategic, tactical, and operational decisions [7].

This research is focused on the design of a waste vegetable oil pickup network from a residual recycling company located in the north of Mexico. Nowadays, the recycling company has 151 clients and wishes to expand by incorporating 49 new generation points (restaurants that generate waste vegetable oil). However, the company that outsources the pickup service is at the limit of its capacity and it is not able to incorporate more clients. Therefore, the company must design a collection network to attend the demand of these new clients.

1.1 Importance of logistics in residual management

Since 2013, with the General Law for the Prevention and Integral Management of Residual, in Mexico, government actions have been carried out to mitigate the environmental and social damage generated by the indiscriminate dumping of waste into the environment. At the beginning of 2019, the Ministry of the Environment and Natural Resources began the Zero Waste Project, which seeks the modification of the current schedule for a new one following the principles of circular economy model [8].

The circular economy is a system designed to be restored and regenerative [9]. The circular economy is an "alternative growth discourse" and not an "alternative to the growth discourse". It is a model that follows a continuous development cycle, preserves and increases natural capital, optimizes resource returns, and minimizes system risks, managing finite stock and renewable flows [10]. This philosophy assumes that the life cycle of a product ranges from its production to its recovery or reduction after it is used [11].

The adoption of a circular economy program implies that the company has to carry out different strategies focused on improving the circularity of its production system and also cooperates with other supply chains to achieve greater efficiency [12]. It is a direct result of a national political strategy and therefore a top-down approach, and its implementation is structured following both a horizontal and a vertical approach [13].

Despite the fact that in Mexico there are more than 100 laws, regulations, and standards for efficient residual management [14], there is still a weakness in the materialization of programs and plans to increase the reuse, recycling, and reduction of waste. Therefore, it is necessary to know the actual generation volume of each residual, the uses that can be given to them in other production chains, as well as determine the capacity that the logistics system must have for it to have value as a raw material.

Given the need for production systems of the industrial sector to be more sustainable, with cleaner processes and a closed life cycle; it is important to design logistic systems that enable the recovery of material and feedstock with a high added value. It is a challenge since the business sector considers that residual recovery processes are not very profitable. Therefore, the continuous improvement of the logistic processes and fundamentally, the optimization of the collection networks is one of the elements is necessary to work seeking to optimize resources.

1.2 Vehicle Routing Problem

One of the fundamental and sensitive elements in the logistics system of reuse is the transport of the residual from the point of generation to the depots of the recovery centre. Currently, there are numerous situations in which it is necessary to manage the transport of products in both directions: customer returns, obsolete products, and seasonal inventories [15], inputs for collection of the waste.

To manage this scenario in an integrated and efficient way, the following elements must be considered:

- The number of clients and their characteristics.
- Location.
- Collection capacity.
- Collection frequency.
- Quantity of a product to be collected.
- Characteristics of the vehicles.
- Human resource.
- Type of product and its characteristics.
- Environmental characteristics.

Carrying out the pickup and delivery of products requires the design of a distribution and recovery system of products in an integrated way, looking forward to the optimization of the vehicle fleet and time. For this reason, mathematical models of vehicle routing problems (VRP) and their variants become tools for finding optimal and feasible solutions. There are two broad categories defined: the homogeneous VRP and the heterogeneous VRP. Homogeneous VRP refers to common characteristics where all nodes handle the same resource such as distance, time windows, returns, and fractional deliveries. Heterogeneous VRP refers to unequal components where each node handles different resources such as vehicle fleet, tanks, trips, and stochastic components in some cases [16].

Homogeneous VRP's are:

- DCVRP. It is a VRP with distance and capacity restrictions, this is the Capacity Restricted Vehicle Routing Problems (CVRP).
- VRPTW. It is a VRP with distance and capacity restrictions, where customers are associated to visit in a certain time-space.
- VRPB. In the VRP with backhauls, consumers can demand or give back some products. Vehicle Routing Problems Pickup and Delivery (VRPPD) is a variant of the VRPB.
- SDVRP. It is a relaxation of the VRP where it allows the same client to be visited by different vehicles as long as the cost is reduced.

Different variants of the VRPPD were developed between 1999 and 2016, in which two situations were considered: a static environment [17], which occurs when all the input data of the problem is known before the construction or design of the routes and the planning horizon is limited, and a dynamic environment [18], where some input data are known or updated during the period in which the delivery and pickup operations of the products takes place. However, most of the delivery and pickup problems have been focused on the static scenario and few authors have worked on the dynamic part of the problem.

The VRP problem with simultaneous deliveries and pickup (VRPSPD) is one of the variants of VRPPD and was first addressed by Hokey Min in 1989 [19], who recognizes that it can exist simultaneously delivered and pickup in the same node. The objective of the VRPSPD is to find a series of routes for a set of vehicles at a minimum cost, in order to serve customers in the most appropriate way, which fulfils the restriction that the vehicles have sufficient transport capacity for the products (or persons) that must be collected and/or delivered and pickup to each customer (node). It must start from a depot and arrive at the same depot. The aim is to find the optimum solution or quality sub-optimal solutions. This is a combinatorial optimization problem and most of its versions are of the NP-Hard class, meaning that the solution cannot be found in polynomial time [20].

Unlike the classic vehicle routing problem, in VRPSPD the feasibility of routes is determined not only by the subset of clients that makes up the route but also, the order in which they are visited. The first condition requires that the total of transported products does not exceed the capacity of the vehicle. The element of order is added because, at all times, the load is a mixture between the product previously collected from the customers visited and those yet to be delivered. Due to the fluctuation in the load, even when the total demand does not exceed the capacity of the vehicles, there may be intermediate points on the route where this does happen [15].

The VRPSPD, like the rest of the problems derived from the VRP, has among its variants the following [21]:

- VRPSPD + heterogeneous fleet, considering capacity, costs, availability, and circulation restrictions as elements of heterogeneity.
- VRPSPD + different maximum route length limitations for each vehicle type, considering the heterogeneous fleet in terms of capacity, cost, and availability.
- VRPSPD + maximum route duration limitation, considering the heterogeneous fleet in terms of capacity, cost, availability, and loading/unloading, and travel speed.
- VRPSPD + soft windows, considering the heterogeneous fleet in terms of capacity, costs, availability, and speed of loading/unloading, and travel.

This last variant is known in the Vehicle Routing Problem Simultaneous Pickup and Delivery with Time Windows (VRPSDPTW) and aims to minimize the difference between routing costs and incomes associated with pickups [20].

VRPSDP is the least studied or applied in the literature and most of the authors consulted assume elements that facilitate the search of a solution, which in some are theoretical solutions that are far away from what happens in real life. Some authors [22] have found optimal solutions using exact methods but have had to make assumptions such unlimited number of vehicles and number of nodes or clients to visit less than 30, this makes it an NP-hard problem.

VRPSPD is one of the least addressed types of VRP in the literature because of its complexity, since the search for optimal solutions can increase exponentially depending on the number of customers or nodes that are part of the problem. Therefore, the computational resources that work with exact algorithms could not be used in scenarios with more than 40 clients. Consequently, the heuristic or metaheuristic algorithms are the most used to find a solution that, even if is not optimal can be feasible.

2 Methodology

The objective of this research was to design a waste vegetable oil collection network to attend the demand of 49 generation sources. Based on the VRPSPD, a mathematical model is designed considering the restrictions of the studied network. Finally, a simulated annealing metaheuristic algorithm was used to obtain a feasible solution.

2.1 Problem Statement

The company increases its client portfolio each year as the capacity to treat residual raises, as well as the awareness of the production chains to have cleaner, more sustainable, and environmentally friendly processes.

The company specializes in the maintenance and cleaning of grease traps, as well as hoods, adding a service of waste vegetable grease collection, which they use for biodiesel production. The grease collection service is outsourced to a company dedicated to the transportation and distribution of products. Currently, that company cannot assume the commitment to include the 49 generation points that the recycling company wishes to add in its client portfolio. Therefore, the recycling company needs to conduct a study to determine if it has the capacity to execute the collection process for new clients. The locations of existing customers and the new ones to be incorporated are showed in Figure 1.

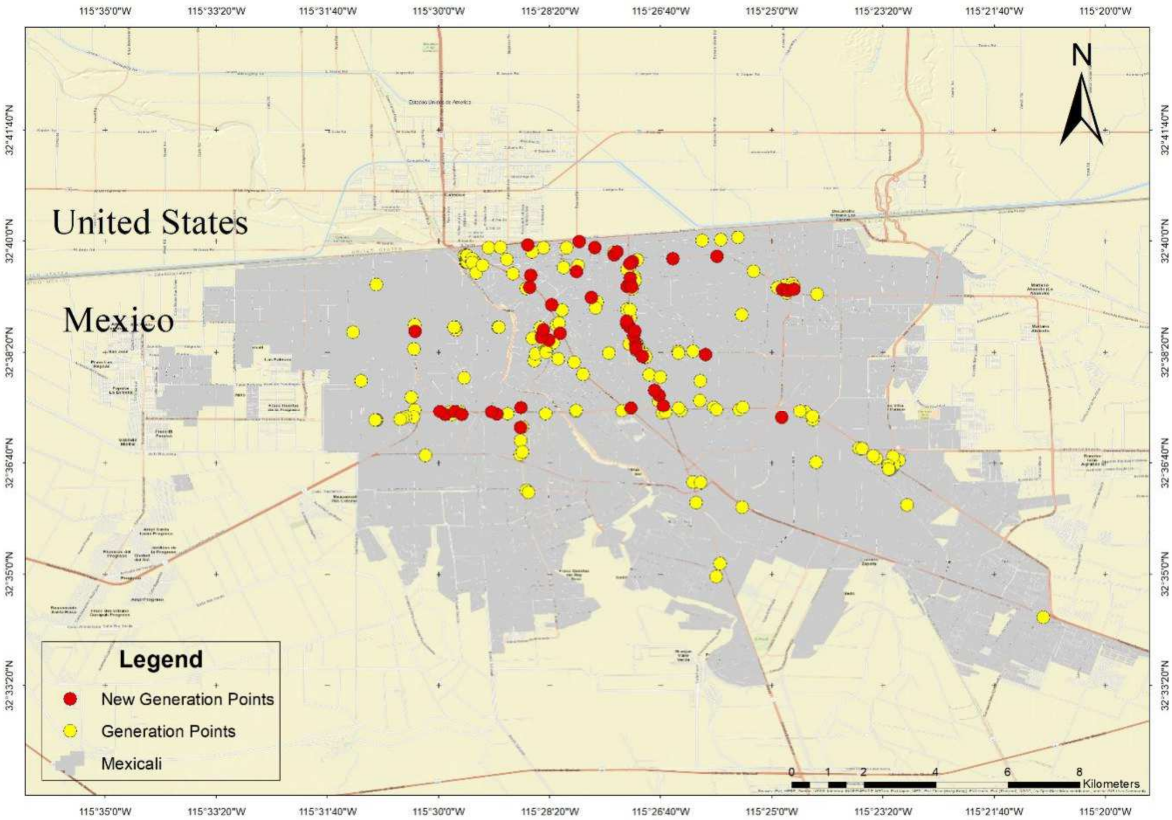

Figure 1 Location of WVO generation points

The objective of the collection process is to deliver empty containers to the points of generation for the collection of residual and to collect containers with WVO. In this process, it is necessary to consider that:

- The generation point will be visited only once; and the opening, closing, and resting times of each point.
- The collection center has two vans, 6 t and 8 t dedicated exclusively to the delivery of empty containers and the collection of full containers at each generation point.
- Deliveries of empty containers and collections of full containers would be made simultaneously.
- 20 L containers will be delivered so that the residual is collected at each generation point.

2.2 *Method of solution*

Knowing the characteristics of the collection process, it is a VRPSPD with elements of a VRPTW, being then a VRPSPDTW. Both models belong to the family of vehicle routing problems with capacity restrictions. Both consider that all routes start and end at the collection centre. At no point of the route can the load exceed the capacity of the vehicle, the vehicles have different capacities and can make at most one trip. For the solution of the problem, it is estimated that the load of the vehicle is a mixture of the products collected from the clients already visited and the one that remains to be visited. Also, it was considered that each establishment has time to attend the vehicle that makes the delivery and collection of the product.

A route is an ordered sequence of customers associated with a specific vehicle. In short, it is a problem where the starting point is a collection centre with a heterogeneous fleet of vehicles and a set of generation points are visited. At each point, there is a demand for 20 L containers, known as delivery demand and 20 L containers containing WVO are for pickup, known as the pickup demand. Both, the collection centre and the generation points have time restrictions to attend the delivery and pickup process. Therefore, a network is designed to satisfy the demand of all customers, optimizing the distance and travel time.

2.2.1 *Design of the mathematical model of the Vehicle Routing Problem Simultaneous Pickup and Delivery with Time Windows*

The objective of the VRPSPDTW is to determine the set of routes that satisfies the demand of all the clients by optimizing the distance, fulfil the demand of the clients, and attending to their time restrictions. The parameters and variables that define the model are shown in Table 1.

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Table 1 Variables and parameters that define the VRPSPDTW

Variables	Parameters
x_{ij}^k: The arc (i,j) with i,j ϵ I^+ is traversed by the vehicle k ϵ K. **t_{ij}^k: Vehicle travel time k ϵ K through the arc (i,j) with i,j ϵ I^+.** $t_{ij}^k = C_{ij}/v^k$ **t_i^k: Time in the vehicle k ϵ K up to the customer i ϵ I.** **s_{ij}^k: Time of service.** $s_{ij}^k = (d_i + p_i) * h^k$ **Dij: Represents the quantity of products to be delivered transported by the arc (i,j) i,j ϵ I^+.** **Pij: Represents the quantity of products to be pickup transported by the arc (i,j) i,j ϵ I^+.** **Cij: Variable to optimize in this case the distance from node i to j.**	**I: Set of clients $I = \{1, 2, 3 \ldots\ldots n\}$ $I^+ = I \cup \{0\}$** **di: Quantity of products to be delivered with i ∈ I.** **p_i: Quantity of products to be pickup with i ∈ I.** **m: Quantity of vehicles.** **Q: Number of vehicles.** **h^k: Loading/unloading speed.** **v^k: Constant associated with the average speed of the vehicle.**

The mathematical model presented is based on the models defined by [20,21,23]. The problem is modelled on a graph, being the vertices the clients and the deposit, so the set I+ and the arcs are the paths between these vertices.

Objective function:

$$min \sum_{k=1}^{m} \sum_{i,j \in I^+} Cij * x_{ij}^k \quad (1)$$

Restrictions:

$$\sum_{k=1}^{m} \sum_{j \in I^+} x_{ij}^k = 1 \quad \forall i \in I \quad (2)$$

$$\sum_{j \in I^+} x_{js}^k - \sum_{j \in I^+} x_{sj}^k = 0 \quad \forall s \in I^+, \forall k \in K \quad (3)$$

$$\sum_{j \in I} x_{0j}^k \leq m^k \quad \forall k \in K \quad (4)$$

$$\sum_{j \in I} D_{oj} = \sum_{i \in I} d_i \quad (5)$$

$$\sum_{j \in I} P_{j0} = \sum_{i \in I} p_i \quad (6)$$

$$\sum_{j \in I^+} D_{ji} - \sum_{j \in I^+} D_{ij} = d_i \quad \forall i \in I \quad (7)$$

$$\sum_{j \in I^+} P_{ij} - \sum_{j \in I^+} P_{ji} = p_i \quad \forall i \in I \quad (8)$$

$$P_{ij} + D_{ij} \leq \sum_{k=1}^{m} x_{ij}^k Q^k \quad \forall i,j \in I^+ \quad (9)$$

$$t_0^k = 0 \quad \forall k \in K \quad (10)$$

$$x_{ij}^k (t_i^k + s_i^k + t_{ij}^k - t_j^k) \leq 0 \quad \forall i,j \in I^+, \forall k \in K \quad (11)$$

$$t_i^k \geq 0 \quad \forall i \in I, \forall k \in K \quad (12)$$

$$x_{ij}^k \in \{0,1\} \quad \forall i,j \in I^+, \forall k \in K \quad (13)$$

$$D_{ij} \geq 0 \quad \forall i,j \in I^+ \quad (14)$$

$$P_{ij} \geq 0 \quad \forall i,j \in I^+ \quad (15)$$

The objective function (1) minimizes the travel distance. The restriction (2) ensures that all customers are visited once. The continuity of the distance travelled from one point is guaranteed by the restriction (3). It (4) ensures that each vehicle is used only once and taking into account that the vehicle fleet is heterogeneous. Restrictions (5) and (6) ensure that everything that is collected is taken to the depot and that everything that is to be delivered is in the depot (7) an (8) ensure that the demands of pickup and delivery at each customer are attended. In the case of (9), it indicates that the product can only be distributed through the arch included in the solution. With (10) it is guaranteed that all vehicles leave the warehouse at the initial moment. The relationship between the arrival times of consecutive customers on a route is defined in the restriction (11), (12) makes the arrival time a non-negative value. Finally, (13) is associated with the domain, and (14), (15) are the non-negative conditions.

2.2.2 The Vehicle Routing Problem Simultaneous Pickup and Delivery with Time Windows solution

Previously knowing the amount of data to process and the complexity of the mathematical model of the problem to be solved, a metaheuristic algorithm was used, to get a feasible solution in less time. Using a metaheuristic algorithm prevents the solution from falling into optimum locations as there are intelligent and high– level procedures. The free software VPRPD was used to solve the problem. This software uses the simulated annealing metaheuristics in its syntax. These metaheuristics has an algorithm that selects candidates randomly and allows degraded solutions, but always with an acceptable probability that will depend on two factors: the control parameters and the difference in values that the objective function takes.

Input data that were used:

- Travel distance matrix between each of the generation points and the collection centre, considering vehicle traffic restrictions.
- Travel time matrix between each of the generation points and the collection centre, taking into account vehicle traffic restrictions.
- Vehicle capacity.
- Workday at the collection centre.
- Number of 20 L containers with waste vegetable oil to collect at each generation points.

- Number of 20 L empty containers to be delivered at each generation points.
- Load time at the collection centre.
- Unload time at the generation points.
- Generation points time window.
- Collection centre time window.

3 Results and discussion

The solution is shown in Figure 2, taking into account the geographical location of the generation points and the collection centre.

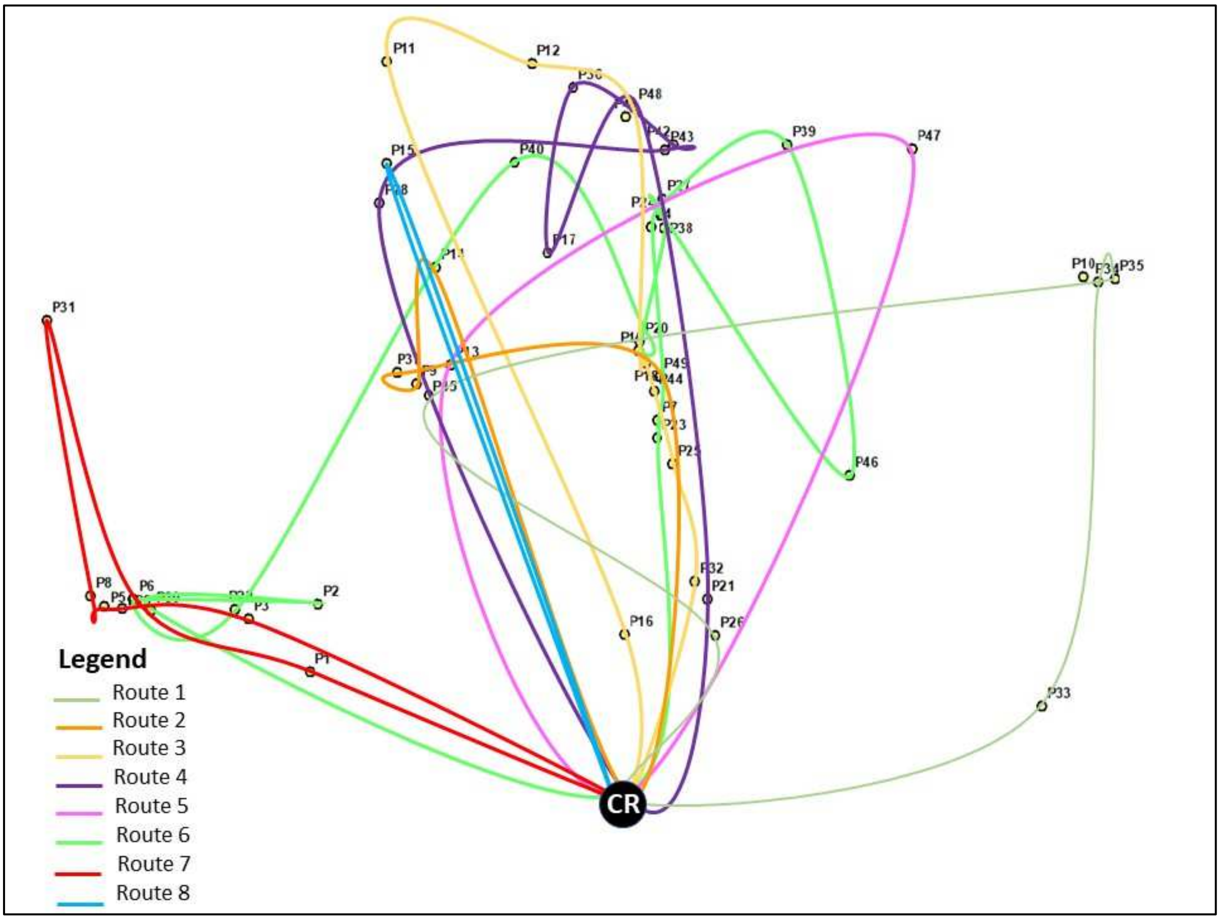

Figure 2 Collection networks for new customers

Table 2 shows a summary of the long times of each route, the distance travelled to execute them, as well as the load transported and advantage of the vehicle's capacity on each trip.

Table 2 Routes of collection of waste vegetable oil

Routes with 6 *t* van		Time (min)	Distance (km)	Load (20 L containers)	Capacity use
1	**CR-P33-P34-P35-P45-P26-CR**	**199.51**	**20.80**	**61**	**90%**
2	**CR-P14-P9-P37-P49-CR**	**140.35**	**14.15**	**23**	**34%**
3	**CR-P32-P25-P18-P10-P41-P12-P11-P16-CR**	**176.68**	**19.40**	**57**	**84%**
4	**CR-P21-P48-P17-P36-P43-P42-P28-CR**	**189.51**	**22.42**	**41**	**60%**
5	**CR-P13-P47-CR**	**148.22**	**16.90**	**56**	**82%**
	TOTAL	**854.27**	**93.67**	**238**	

Routes with 8 t van		Time (min)	Distance (km)	Load (20 L containers)	Capacity use
6	**CR-P30-P2-P29-P22-P40-P20-P19-P38-P24-P46-P39-P27-P4-P44-P7-P23-CR**	**469.47**	**26.42**	**169**	**50%**
7	**CR-P1-P6-P31-P8-P5-P3-CR**	**378.29**	**18.41**	**37**	**11%**
8	**CR-P15-CR**	**538.61**	**14.60**	**256**	**75%**
	TOTAL	**1,386.37**	**59.43**	**462**	

It will not be possible to make all the visits on a working day, because the time it takes to make all the visits exceeds the workday established of the collection centre. Therefore, it should be considered when scheduling the delivery and collection process.

The allocation of the load in the vehicles is acceptable, however, the capacity use of the 8 *t* Van is only 46 percent, while the utilization of the 6 *t* Van capacity is 70 percent. Finally, the use of the dynamic capacity of the vehicle is low, which could impact badly in the efficiency of the distribution process.

4 Conclusions

It is appropriate to carry out a strategy to prevent pollution that allows the creation of an environmental training supported by strategic, tactical and operational decisions, that are the bases for the design of a recovery logistic system, permitting the evaluation of the waste generated in the current supply chain.

The collection is a fundamental process of the recovery logistic system, which consist of collecting the waste and deliver the container for its later collection, this task is only possible by connecting all the waste generators with the collection centre throughout the design of a collection and distribution network. Therefore, the waste vegetable oil collection is a vehicle routing problem with simultaneous deliveries and collection, considering time restrictions and a heterogeneous vehicle fleet.

The VRDSPTW is a complex problem, due to the process's restrictions and the number of nudes that form part of the network, therefore, it was necessary for the current problem the utilization of simulated recursive metaheuristic, which made possible to reach a feasible solution in less time, obtaining 49 WVO generation points. Finally, the analysis of the previous results obtained by the free VPRPD software, showed 8 routes for a vehicle capacity utilization of 70 percent in the 6 *t* vehicle and 46 percent in the 8 *t* vehicle, highlighting lower exploitation of the dynamic capacity.

The results presented in this investigation are the beginning of a project to design a logistic system for the recovery of waste vegetable oil. Therefore, in future studies the following elements should be considered:

- Perform a comparison with future results by using other metaheuristics to select the most feasible solution.
- Analysis of the collection centre's capacity to deal with an increase in the volume of residual to be collected.
- Include transport indicators as restrictive elements of the model.
- Combine the collection of waste vegetable oil generated by the restaurant and the domestic sector.
- Make an assignment of the clients that would be attended by the collection centre itself and by the contracted company, seeking better use of vehicular capacity and resource optimization.

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THE APPLICATION OF SMED METHOD IN THE INDUSTRIAL ENTERPRISE

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Abstract: The production process fluency is often interrupted by idle time. A significant proportion of individual idle times is caused by changeover. Trends, such as the individualization of requirements, the constant effort to meet the customers' requirements on time and the maintaining of the production process fluency at low costs, are aimed at eliminating idle time. In terms of contradictory goals such as individualization of customer requirements, which is reflected in the high variability of production / products and minimalization of the production time and its fluency, it is necessary to pay increased attention to the changeover process. The problem related to the changeover process can be solved in two ways: by reducing the number of changeovers (reducing production variability and achieving dissatisfaction with individual customer requirements) or by shortening the changeover time (while maintaining production variability and ability to satisfy a wide range of individual customer requirements). The Single-Minute Exchange of Die - SMED method is used to shorten the time duration of the changeover process and eliminate waste in the given process. The aim of the paper is to apply the SMED method in vibration welder changeover process in a selected industrial enterprise and thus achieve a shortening of the changeover process. The SMED method was applied in the enterprise which belongs to the group of small and medium-sized enterprises. The research method was indirect observation via video recording and time snap. Various types of waste were identified based on the analysis, and subsequently eliminated by proposed rationalization measures. Finally, the time duration of the changeover process before the analysis and after the implementation of rationalization measures was compared.

1 Introduction

The current business environment is characterized by turbulent changes and competitive pressure. There are several competing enterprises in each branch of industrial production. It means that potential customers have the opportunity to choose from several suppliers who are able to meet their individual requirements (price, quality, quantity, deadline, etc.). Individualization of products is a characteristic feature of 21st century manufacturing enterprises. Individualisation of products has led to comprehensive planning and control systems that make difficult a mass production of products [1]. Due to the fact, that the primary goal of every enterprise is to make a profit, and competitive pressures and individual customer requirements force enterprises to reduce costs, the only option for enterprises is to pay attention to those activities and processes that can be made more efficient by eliminating waste.

Aforementioned facts have stimulated the emergence and implementation of the lean manufacturing concept, whose sophisticated tools help reduce waste and meet customer needs at the lowest possible cost.

1.1 Lean production

The term "lean production" was first introduced by Womack in 1990 in the book The Machine that Changed the World [2]. However, the origins of lean management as a holistic concept date back to Japan (1950s) and is generally attributed to Toyota Company, whose production system is known as the Toyota Production System (TPS).

The mentioned management system can be described as production without everything unnecessary, i.e., a resolute reduction of the failures/defects and costs in production, saving space and time. It is a leaning of production management and a considerable decentralization to lower levels of production management. It specifies what creates and does not create value for customers [3].

Košturiak et al. [3] state that "lean" is a dynamic process of change that is driven by a systematic set of principles and best practices aimed at continuous improvement. Liker [4] explains that lean manufacturing is a philosophy that shortens time between the customer order placement and product delivery by eliminating sources of waste in the production flow. Alukal [5] shares this opinion and adds that lean helps enterprises to reduce costs, cycle times and unnecessary, non-value-added activities what is leading to a more competitive and agile business.

According to classical theory, lean manufacturing means producing simply in self-controlled production. It focuses on reducing costs via uncompromising efforts to achieve perfectionism. Every day in production includes the principles of Kaizen activities, flow analysis and Kanban systems. The effort involves all employees of the enterprise into changes - from top management to production workers. Lean manufacturing is not purposeless reducing of costs. It is primarily a maximization of added value for the customer. Lean is a way for enterprises to produce more, have lower overhead costs, and use their areas and production resources more efficiently [6].

The critical point on which lean manufacturing or lean enterprise focuses is value. The value can be formed in two ways:

1. The enterprise can reduce production costs by minimizing or eliminating waste or
2. by introducing other services that add value to the product and will be appreciated by the customer.

Waste refers to all activities, material or elements that do not add value to the final product or service [7]. At the same time, these activities or elements can also increase the product or service price, which the customer is not willing to accept [8]. In Japan, such a waste is marked by the word Muda. Muda means everything that uses / consumes the enterprise's resources but does not create value. Taiichi Ohno categorized the seven types of waste (Table 1).

Table 1 Seven types of waste by Taiichi Ohno (authors own elaboration according to [9,10])

	Type of waste	Description
1.	Overproduction	Production of more products than necessary for immediate use.
2.	Waiting	Idle time, waiting for material, machine, information and protracted decisions.
3.	Transportation	Excess transport and handling of products, semi-finished products and materials.
4.	Motion	Unnecessary movement of people (walking, reach) excessive physical activity.
5.	Inventory	Excess inventories of materials finished products and work in progress.
6.	Excess processing	Excess work, consumption of materials and production resources.
7.	Defects	Any production that results in reprocessing or scrap production.

Aforementioned seven basic types of waste are supplemented by the 8th type of waste: People - the untapped potential of employees and their creativity [11].

1.2 Changeover of machine

The time when large amounts (series) of narrow product assortments were produced is irretrievably gone. It is necessary for today's market to meet changing customer requirements. In order to ensure that customer requirements are met, the flexibility of business processes (the production of small production batches), is crucial. Therefore, the demand for "single and large quantity" products has gradually turned into a "high-mix and low volume" product demand. The set system requires frequent changes of production batches, therefore short changeover times of machines and production lines are required [12,13].

When analysing the different types of machine idle times that have a significant impact on its availability / production capability, the time required for changeover is one of the most critical times. The time related to the machine changeover to another order is the time when the machine or line is not producing. It can also be a source of problems in managing production in small batches. When the process of changeover takes a long time, production management can use two ways to solve the issue. The first one is to combine related production batches into large quantities to minimize the number of machine changeovers. The second way, which is generally better comparing to batches combination, is to find the causes of long changeover times [14].

The term changeover can be understood from three perspectives. The first one, narrow point of view, defines the time when the machine is between two production batches. The second one, more broadly understood point of view is explained as the time between the production of the first production batch last piece and the production of the first good piece of the next production batch. Figure 1 shows the second point of view of the changeover process.

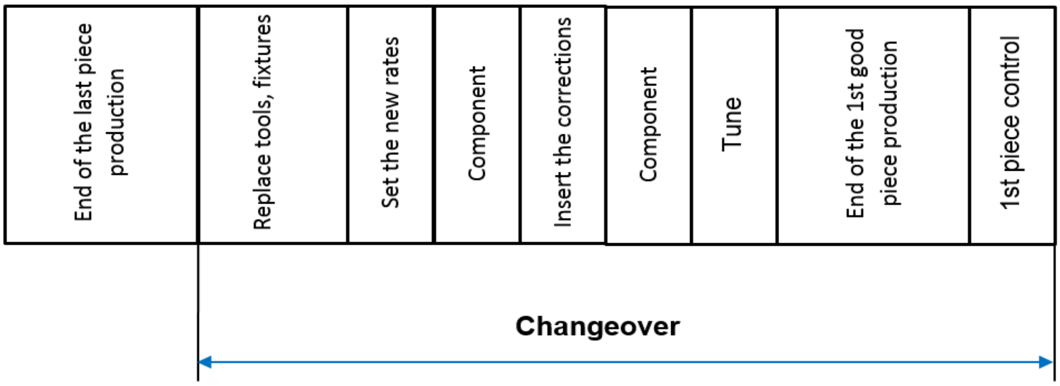

Figure 1 Changeover process [12]

The third explanation of the term focuses on speed and explains changeover as the time between the standard speed of the first production batch and reaching the standard speed of the next production batch [15].

To shorten the changeover times, it is necessary to identify and analyse waste that prolongs the change in production batches. The basic types of waste include [16]:

- searching,
- walking,
- waiting,
- missing standards,
- insufficient planning,
- calibration,
- missing tools.

1.3 SMED method

The Single-Minute Exchange of Die - SMED method is used to reduce waste in the production system, shorten the production lead time and standardize times of machine change activities [17]. The goal is the change from one product type to another in the shortest possible time and in the most efficient way. Many enterprise states that methods for reducing changeover time require investment. In fact, the failure to implement a rapid changeover system causes the enterprise increased costs due to ide time between production batches. Achieved time savings will enable the enterprise to produce products faster, which will also reduce delivery time [18]. Implementation of the mentioned SMED method also improves the level of safety and ergonomics in the enterprise [19]. The whole procedure of the method implementation is based on a detailed analysis performed directly at the workplace [12]. The method is based on the following basic steps [20]:

1) separation of internal and external changeover activities,
2) reduction of internal activities time,
3) reduction of ‘external activities time,
4) reduction of the changeover process time.

The differentiation of internal and external activities is based on the current situation analysis, which is usually carried out via video analysis [19]. In the first step, the question, whether the activity is performed internally or externally is answered [12]. Internal activities can be implemented only after the device has stopped running [21,22].

The time of internal activities is considered idle time. Internal activities include activities such as checking device replacement or disassembly of the toll from the machine [12]. On the other hand, external activities can be implemented during the machine production, before and after the production machine changeover [23]. Activities are performed outside the machine and include operations such as preparing tools or bringing forms from storage.

If the activity is internal, the question of what measures are needed for the transformation between external activities is answered. If it is not possible to transfer the activity to external one, it is necessary to propose the measures to shorten its duration [12]. Enterprises can reduce changeover time by improving work organization. Typical failures in the incorrect work organization include the preparation of tools, work aids, maintenance of tools, but also transport operations carried out only after the machine has stopped running [19].

The third step focuses on measures that can reduce the time of external activities [12]. The reduction of external changeover time is mainly due to the improvement of the workplace organization [20]. Improving of storage or tools and forms transport contributes to improve the whole process of changeover and can minimize the search or unnecessary movement of employees [24].
At the same time, it includes also a constant reduction of internal and external changeover time. In the last step, enterprises try to eliminate the changeover process especially by standardizing parts.
There are general recommendations to eliminate waste and achieve rapid changeover, which include [19,20]:

- standardization of changeover activities,
- standardization of machines,
- visualization of the changeover process,
- parallel execution of operations,
- use of quick couplers,

• use of automatic tools,
• automatization of the changeover process,
• creation of changeover teams.

1.4 SMED method in the context of Industry 4.0

The last stage of production management development is the Industry 4.0 paradigm which aims to connect the physical and cyber worlds with the latest technologies [26]. It represents the integration of the Internet of Things and the Internet of Service into the production environment. The interconnection of machinery, warehouses and production lines creates a cyber-physical system (CPS) which uses cloud access to record and process large amounts of data and thus create the basic concept of Industry 4.0 [27].

Lean manufacturing and digitization or Industry 4.0 appear to be two different approaches. One is more a philosophical and organizational approach (lean manufacturing) and the second one focuses on technology (digitization) [28]. Lean management methods use simplification and standardization to manage the complexity prevalently at the expense of flexibility. Digitization has the ability to counter the deficit [29]. However, approaches represent two paths with the same goals, increasing efficiency and productivity [28]. Hoellthaler, Braunreuther and Reinhart refer to digitization as another development step of lean management in production processes [29]. Industry 4.0 creates space for building a lean enterprise. It enables easier and more comprehensive understanding of customer requirements and needs (Big Data), as well as immediate sharing of necessary data through complex supply chains and networks. Smart enterprises can produce more with less waste. Industry 4.0 also enables faster "one-piece flow" of customized products and has the potential to rapidly reduce inventory through efficient deliveries [30].

The authors Hoellthaler, Braunreuther and Reinhart stated that lean philosophy has reached its limits at the time with the constantly increasing complexity of production processes, for example due to the accumulation of information and its interconnection, increasing volatility and accelerating the growth of time pressure. Digitization offers an opportunity to overcome the limits of lean manufacturing by increasing the ability to manage the complexity and by increasing flexibility. The digitization requires a lean foundation as a prerequisite for creating a maturity-based model regarding "lean" and "digital" in the mentioned theory.

Furthermore, the authors Hoellthaler, Braunreuther and Reinhart points out, that the level of readiness for digitization is proportional to the number of employees in the enterprises, which means that the less employees the enterprise has, the less it is digitized. Therefore, particulary SME particular have a deficit in terms of digitization, as they create the largest share of non-digitized enterprises [29].

Strategic management literature explains that SMEs often lack a comprehensive strategy, Information Technology (IT) maturity and technical expertise to cope with major technological revolutions in the industry [31]. In reality, majority of manufacturers, SMEs in particular, can only digitize certain areas of thein operations, such as digitizing thein customer relationship management or production planning and control [32].

Theoretically, lean manufacturing principles and procedures can be successfully implemented in the traditional way and without using IT resources. But on the other hand, based on practical experience, it is recommended that IT tools should be key to achieve LM efficiency in the 4.0 industry era. The integrative nature of IT allows lean manufacturing processes to integrate and support each other [26].

In addition, the production or process controllers use (e.g. distributed control system, control and data acquisition supervision, programmable logic controller and remote terminals) jointly with industrial robotics and software allow machines to automatically control production orders, identify product types and further load the appropriate program and installation of the right tools without manual intervention, features that facilitate SMED and remove non-value added activities from the changeover process [26].

The aim of SMED is to reduce downtime and cost caused by setup processes. Increased flexibility through short setup times support the production of small lots while achieving short lead times and maintaining a low level of stock [33]. It is expected that the highest impact on setup time will have in addition to augmented reality and plug and play also additive manufacturing. As additive manufacturing processes are not product-specific, therefore the varying work-pieces can be produced with minimum setup times. Times for selection, search and tools and work pieces adjustment are omitted. On the other hand, small adaption, temperature adjustments and etc. will still incur.

The authors Feldmann and Gorji has stated that SMED can also be applied to additive manufacturing. Considering that setup times are already technologically reduced to a minimum, the impact is expected to be rather small. However, SMED will remain of fundamental importance for reducing the physical setup time [34].

SMED and Industry 4.0 SMED is used to reduce changeover time. As was mentioned before, the Industry 4.0 uses tools like plug and play, modular manufacturing, and additive manufacturing to reduce the setup time. Some of the tools were identified by [33]. as Industry 4.0 tool, which can be linked SMED method application. The tools are as follows: additive manufacturing, plug and play, virtual reality, auto-ID, digital object memory, digital twin/simulation, real-time computing, machine learning [33].

2 Methodology

The data obtained by observation in a selected industrial enterprise were used as a basis for the paper elaboration. Selected industrial enterprise is focused on exterior and interior mirrors production and direction indicator for cars. The authors of the paper will pay attention to the changeover process on the line producing direction indicators.

The subject of the current state changeover analysis will be the vibration welder. The vibration welder changeover is performed in the enterprise due to the change of production batches from one type of product to another one after the weekly required (planed) production is fulfilled. The reason for changeover process was the long changeover time, as well as the fact that changeover occurs 5 times per week. At present, the changeover is performed by two employees (Maintenance worker 1 and Maintenance worker 2, as well as by quality employee who approve the release of products based on quality criteria and also by production operators, who are needed in the first piece's production.

The basic research method was indirect video observation. The video was recorded by two moving cameras, which monitored the sequence of employees work individually. AVIX SMED software was used to process the acquired video data. The videos were also processed separately in the software. Although the videos were recorded and uploaded into the software separately, it was necessary to determine the links between the employees' activities in the software, as some activities are interdependent.

Based on the analysis, the wastes were identified and subsequently eliminated by rationalization measures. In the end, the current duration of the changeover process and its duration after the implementation of rationalization measures was compared.

3 Analysis of the vibration welder changeover process

The enterprise where the analysis and subsequent application of the SMED method was performed to improve the changeover process can be included among the medium-sized enterprises. Recently, the enterprise has begun to focus on the implementation of smart solutions and elements of Industry 4.0 in the form of collaborative robots. However, in the area of machine changeover, the enterprise does not apply any elements of Industry 4.0. AviX software was used to analyse the current state of art of changeover process. Due to the sensitivity of some data and the enterprise's request, the paper do not include print screens from the software.

As was mentioned before, the changeover is performed by Maintenance 1, Maintenance 2, quality employee and production operators. In order to perform the required exchange, it is necessary to bring the vibration form from warehouse remoted 50 meters from the line. Maintenance personnel must walk to the warehouse, locate the appropriate form according to the project number and load it on the positioning trolley. One maintenance worker must pick up and transport the trolley with form to the line where the exchange will take place. The second maintenance worker will ensure the transport of the empty trolley needed to store the old form to the line. The next step is to replace the vibration form. The exchange of vibration forms consists of the specific activities listed in Table 2 and Table 3.

After the changeover process, it is necessary to transport the trolley with the old form to the original place in the warehouse and return for the empty trolley. These activities are provided by only one maintenance worker while the other maintenance worker performs the changeover process.

4 SMED method implementation

The implementation of the SMED method for reducing the changeover time was performed based on the procedure shown in Figure 2. The authors of the paper were focused on the first 5 steps.

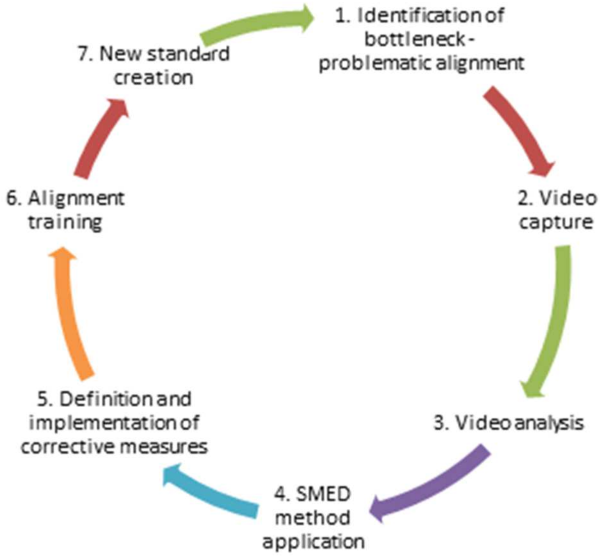

Figure 2 Procedure of SMED method implementation (authors of the paper own elaboration according to [12])

1) The identification of a bottleneck consists of production facility determination to which the SMED method will be applied. To determine the bottleneck, value stream mapping or the overall efficiency calculation of the production facility is used. The workplace that determines the total capacity of the production system is chosen. In this case, it is a line producing direction indicators which has an impact on the entire exterior mirror production. The production equipment is a vibration welder, which changeover process is problematic from an organizational and time point of view.

2) The video capture is necessary to collect the information needed to perform a current state analysis of the production equipment changeover process [35].
3) Video analysis of the changeover process was performed using AviX SMED software. The work of individual maintenance workers was divided into separate activities with their duration (Table 2, Table 3). Activities are categorized into 4 groups according to their meaning: Necessary activities, Value added activities, Loss or Waiting.

Table 2 Maintenance worker 1 activities (authors of the paper own elaboration, 2019)

Activities	Duration [s]	Meaning
Walking to a new form	18.8	loss
Searching for the form	8.5	loss
Waiting for trolley positioning	26.1	waiting
Loading the form on the trolley	4.6	necessary activities
Moving with the empty trolley to the welder	27.1	loss
Walking around the welder	15.8	loss
Inserting the centring pins	19.5	value added activities
Carrying the table up to the stop of the centring pins	23	value added activities
Loosening the upper screws	37.2	value added activities
Waiting for the Maintenance worker 2	8.3	waiting
Dropping the table to the tool change position	8.7	value added activities
Problem loosening of centring pins	31	loss
Loosening the 2 lower screws	37	value added activities
Pulling the pins out of the form	3	value added activities
Shifting the unlocked form	2.2	value added activities
Walking for the new form (behind the welder)	12.1	loss
Bringing a new form to the welder	9.9	value added activities
Moving the new form to the welder	7.3	value added activities
Walking to the front of the welder	16.4	loss
Centring the shape with the centring pins	20.3	value added activities
Tightening the lower screws by hand	4.1	value added activities
Tightening the lower 2 screws with the key	27.7	value added activities
Taking the table up to the stop	14.5	value added activities
Tightening the upper screws	41.6	value added activities
Securing the table at the bottom	9.4	value added activities
Removing the centring pins	10.6	value added activities
Implementing a parameter set	26.7	value added activities
Bringing the preheating device to the line	35.6	necessary activities
Installing a preheating device	33.5	value added activities
Automatic tuning of the head and welding of the 1st pieces to perform a destructive test	79.4	value added activities
Destructive test	40	value added activities
Waiting for production release	155.4	loss
Releasing the production by quality worker	33.4	necessary activities

Table 3 Maintenance worker 2 activities (authors of the paper own elaboration, 2019)

Activities	Duration [s]	Meaning
Walking for the form	19.8	loss
Moving the trolley to the form	5.4	necessary activities
Trolley positioning	32.4	necessary activities
Transporting the form to the welder	33.6	necessary activities
Waiting for the welder release by the Maintenance worker 1	50.3	waiting
Walking to the welder door	4.7	loss

Opening the welder rear door	4	necessary activities
Loosening the screws on the upper form	28.2	value added activities
Closing the welder door	10.8	necessary activities
Waiting for the Maintenance worker 1	39.1	waiting
Walking to the welder door	2.7	loss
Opening the welder door	3.1	necessary activities
Loosening the 2 bottom screws	21.7	value added activities
Pulling the connectors out of the form	11.1	value added activities
Moving with the empty trolley to the welder	5.3	necessary activities
Loading the form on the trolley	6.7	necessary activities
Moving the trolley sideways	7.3	necessary activities
Adjusting the trolley towards the welder	7.3	necessary activities
Moving the form into the welder	6.3	value added activities
Connecting the connectors	26.8	value added activities
Tightening the bottom screws	41.5	value added activities
Closing the welder door	7.9	necessary activities
Waiting for the Maintenance worker 1	12.7	waiting
Walking to the welder door	3	loss
Opening the welder door	4.6	necessary activities
Tightening the screws of the upper form	24.4	value added activities
Closing the welder door	6.2	necessary activities
Moving the empty trolley from the new form	31.6	necessary activities
Walking for the form	19.2	loss
Moving the trolley with the old form	28.5	necessary activities
Trolley positioning	13.9	necessary activities
Inserting the form into the rack	15.8	necessary activities

Figure 3 shows the percentage of Value-added and Non-value-added activities in the changeover process performed by Maintenance worker 1. Most of the activities carried out were Value-added activities in the process. The total duration of the activities carried out by the Maintenance worker 1 was 848.6 s, as he ensured the entire changeover process, from the preparatory activities to the release of production by the quality employee. All activities within the changeover were carried out only after the production equipment has stopped running, i.e. all activities can be marked as internal activities. The operator was waiting for the maintenance worker to perform a destructive test, instead of preparing the components, and then started preparing the components.

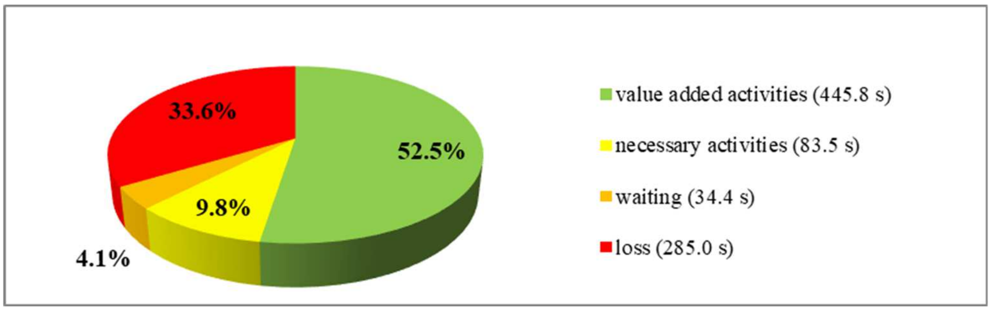

Figure 3 Activities categories of the Maintenance worker 1 (authors of the paper own elaboration, 2019)

Figure 3 shows that Value-added activities create 53% (445.8 s) of the changeover activities total duration. Non-value-added activities have a duration of 402.9 s, which represents 47%. From the Non-value-added activities time are 285 s Losses (34%), 34.4 s (4%) Waits and 83.5 s (10%) represent Necessary activities.

Figure 4 shows the percentage of Maintenance worker 2 individual activities. The total duration of the Maintenance worker 2 performance is 536 s, due to the fact that Maintenance worker 2 participates in the process of changeover only in part of the certain activities' implementation.

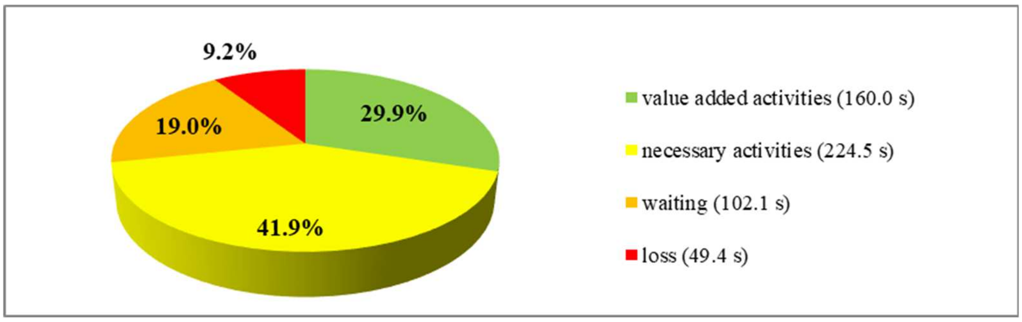

Figure 4 Activities categories of the Maintenance worker 2 (authors of the paper own elaboration, 2019)

Figure 4 shows that Non-value-added activities predominate - 70% (376 s) of the Maintenance worker 2 activities total duration. Activities in the Value-Added category create 30% (160 s) of the process. Within the category of Non-value-added activities, the largest percentage is represented by Necessary activities - 42% (224.5 s). Waste in the form of Waiting has a duration of 102.1 s (19%) and Losses represent a 9% (49.4 s) share of Non-value-added activities.

Figure 5 is a summary percentage of the changeover process current state. It contains the duration of the activities of both maintenance workers, which represents a total of 1384.7 s. Value-added activities represent 44% (605.8 s) and Non-value-added activities 778.9 (56%) of the total changeover time. Within Non-Value-Added Activities, Losses have a duration of 334.4 (24%), Waits 136.4 s (10%) and the Time of Necessary Activities is 308 s (22%).

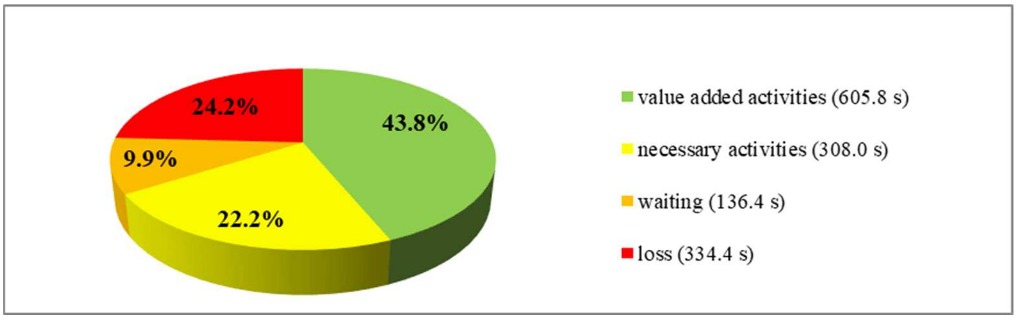

Figure 5 Activities categories of the changeover process (authors of the paper own elaboration, 2019)

Based on the current state changeover analysis, the following wastes were identified:
- Walking: long distances that maintenance workers have to walk to secure a new form. It is 50 m between the workplace and the form warehouse, where also a preheating device is stored and its delivery and installation are provided by a Maintenance worker 1:
- Locating the form in a rack.
- Walking: walking of maintenance workers when changing a new form (replacement must be done by the maintenance workers together, as the form is heavy). Maintenance worker 1 must move from the front of the welder behind the welder, to the workstation of Maintenance worker 2, move the new form to the welder and then move back to his original place.
- Waiting: monitoring the work and waiting for the Maintenance worker 1 to complete his work. It results from the mentioned links between activities (unnecessary movement of Maintenance worker 2 due to monitoring the colleague and after completion of activities performed by Maintenance worker 1 return to his workplace)
- Waiting for the release of production by quality employee.
- Repeated performing of operations when tightening the screws with a ring spanner.
- Tightening and loosening the screws on the upper and lower part of the form is performed separately
- The biggest idle time was waiting for part release, which includes the actual production of parts by the operator to enable the quality check of the parts by the team leader.

4) Application of the SMED method. To optimize the process, the previously described procedure of the SMED method consisting of 4 steps is used, with the aim to perform activities more efficiently [35]. The method is based on 4 basic steps [20]:

a) In the first step, the authors divided the activities into internal and external according to whether they can be implemented during the operation of the production equipment or whether the machine needs to be shut down. The following Maintenance worker 1 activities were classified as external activities:

- walking to a new form,

- searching for form,
- waiting for the trolley positioning,
- loading the form on the trolley,
- moving an empty trolley to the welder,
- walking around the welder.

In the case of Maintenance worker 2, the following activities were included among the external activities:

- walking for form,
- moving the trolley to the form,
- trolley positioning
- transferring with the trolley to the welder,
- returning an empty trolley from a new form,
- walking to the welder,
- returning the trolley with the old form,
- trolley positioning,
- placing the old form on the rack.

The internal changeover time (Maintenance worker 1) decreased from the original 848.6 s to 754 s by including and regrouping activities from internal to external ones. For Maintenance worker 2, the time of internal activities was reduced to 335.8 s.

b) The second step is aimed at eliminating the time of internal activities (performed during the shutdown of the production facility), which will be achieved by the proposed measures (Table 4).

Table 4 Proposed measures to eliminate the internal activities time (authors of the paper own elaboration, 2019)

Waste	**Proposed measures**	**Benefits**
Watching the Maintenance worker work by Maintenance worker 2	Loud informing a colleague about the operation completing	Elimination of unnecessary walking (movement)
Multiple tightening of screws with ring spanner	Procurement of a pneumatic screwdriver	Elimination of multiple screw tightening
Tightening and loosening the screws on the upper and lower part of the form carried out separately	Tightening and loosening the upper and lower screws at the same time	Elimination of unnecessary walking (movement)
Moving to the warehouse and transporting the form.	Procurement of a trolley with a push-pull drive	Form change performed by one maintenance worker, improvement of ergonomics, elimination of unnecessary movement
Waiting for the operator to prepare the components for the destructive test by the Maintenance worker 2	Preparation of components during the destruction test	Reduction of idle time

c) The third step of the SMED method is to reduce the time of external activities performed during the changeover process by implementing the measures listed in Table 5.

Table 5 Proposed measures to eliminate the external activities time (authors of the paper own elaboration, 2019)

Waste	**Proposed measures**	**Benefits**
2 employees need to transport the form to the machine	Procurement of a trolley with a push-pull drive	Elimination of external activities of the Maintenance worker 2 related to transfer of the form to the machine,
The long distances that maintenance workers have to walk to secure a new form	Changing the position of the rack with forms and preheating equipment	Shortening the length of the walk
Looking for the form in the rack	Colour resolution of form labels	Elimination of the form search

The colour resolution of the form labels according to its affiliation to the individual projects is shown in Figure 6.

Project type	**Colour resolution**
Project 1	
Project 2	
Project 3	
Project 4	
Project 5	

Figure 6 Proposed colour resolution of the form labels (authors of the paper own elaboration, 2019)

d) The fourth step is reduction of the total changeover time.

In the fourth step, the goal is to reduce the total time of internal and external activities in the changeover process. The proposed measures of an organizational nature are as follows:

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- the preheating device is brought and installed by the Maintenance worker 2,
- external activities performed by the Maintenance worker 2 connected with the removal of the form from the previous production will be performed by the Maintenance worker 1.

The percentage of individual activities categories of both employees after the implementation of the above-mentioned solutions is shown in Figure 7 and Figure 8.

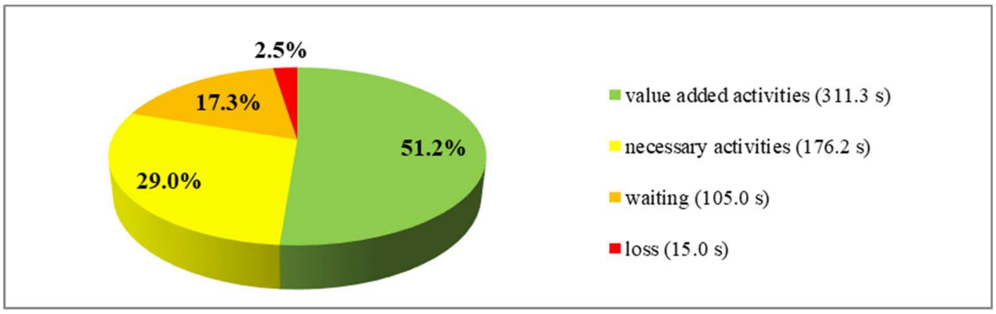

Figure 7 Activities categories of the Maintenance worker 1 after the measures' implementation (authors of the paper own elaboration, 2019)

Figure 7 shows that after the proposed solutions / measures implementation in the form of activities division into internal and external ones and regrouping of activities between employees, Value added activities represent 51% and Non-value-added represent 49% of the total duration of activities performed by Maintenance worker 1. Although the percentage Non-value-added activities increased, a significant decrease was reached in activities Losses.

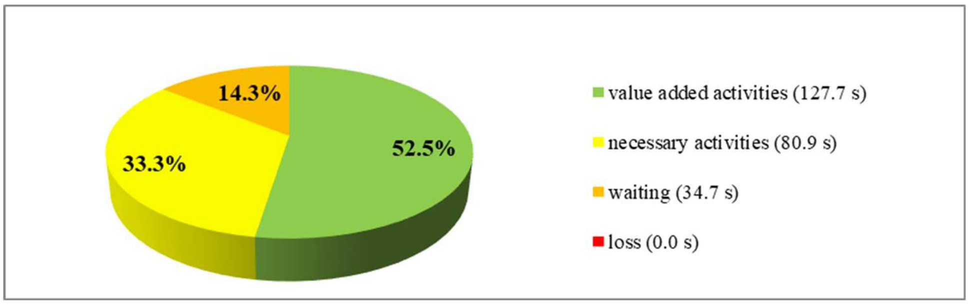

Figure 8 Activities categories of the Maintenance worker 2 after the measures' implementation (authors of the paper own elaboration, 2019)

Figure 8 shows the percentage of activities performed by Maintenance worker 2 after the implementation of the proposed solutions. The graph shows that Value-added activities represent 52% of the total changeover time and Non-value-added activities 48%. From the activities performed by Maintenance worker 2, all activities that represented a loss in the process were eliminated. For other activities included in the category Non-value-added activities, there was also a percentage decrease in the share in the changeover process. The percentage of Value-added activities has increased from the original 30% to 50%.

Figure 9 shows the change in the share of individual activities in the overall changeover process.

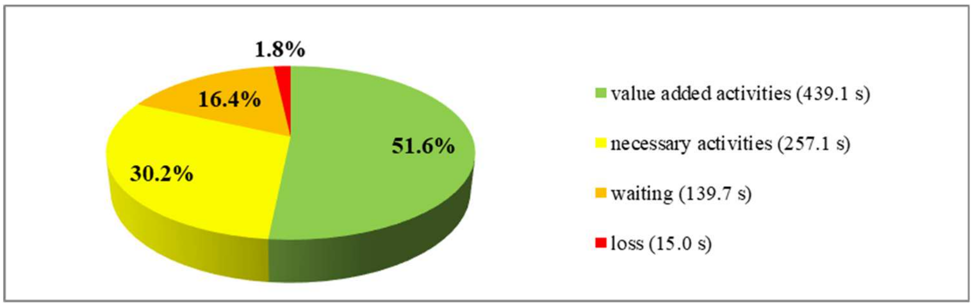

Figure 9 Activities categories of the changeover process after the measures' implementation (authors of the paper own elaboration, 2019)

From Figure 9 result that most activities in the process add the value (52%). Non-value-added activities represent 48% of the changeover process.

A comprehensive evaluation of the proposed solutions aimed at improving the changeover process is based on a comparison of the previous changeover time and the changeover time after the implementation of all corrective measures. The changeover process time has been reduced from the original 848.6 s to 607.5 s. In the previous changeover process, all activities were performed during shutdown of the equipment, indicating that the changeover time was considered idle time.

After applying the first step of the SMED method – division of specific activities into internal and external categories, the idle time (changeover time) was 754 seconds (time duration of internal changeover activities). It the changeover time (607.5 s) after the implementation of corrective measures, external activities that are performed during the operation of the welder are also included. The changeover time, which includes only internal activities that represent idle time, is 480.8 seconds.

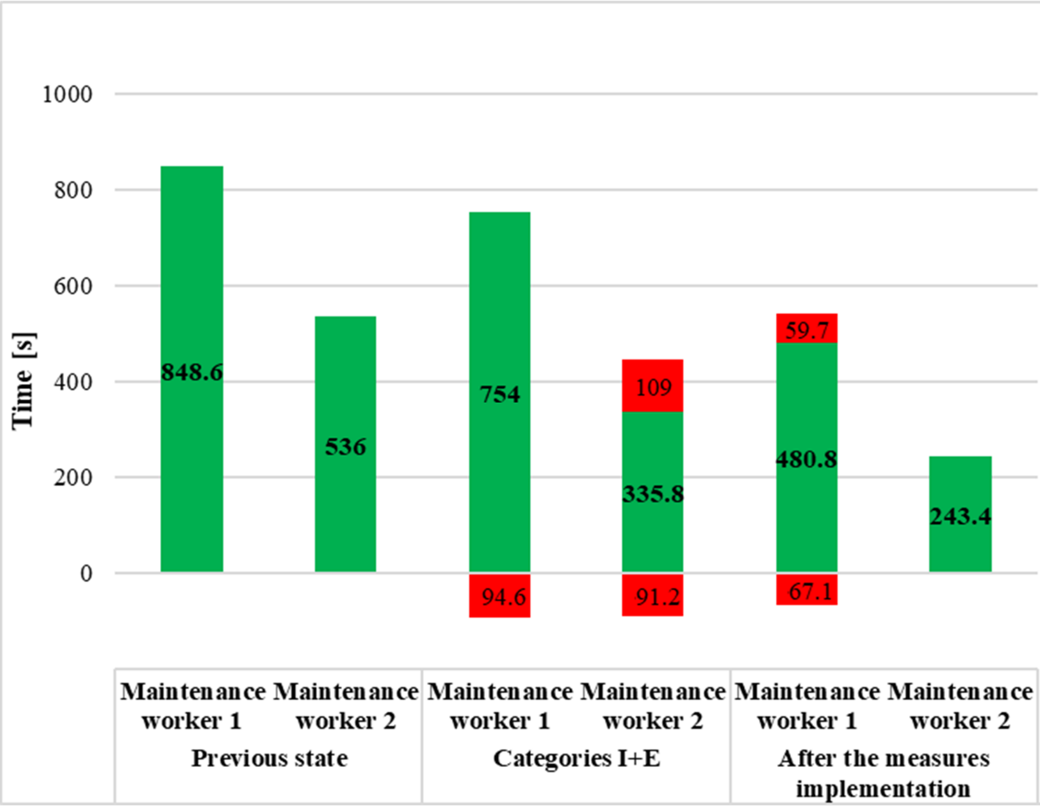

Figure 10 Time duration of the changeover process (authors of the paper own elaboration, 2019)

From the abovementioned results that the idle time was reduced by a total of 367.8 s. The authors of the paper also consider the percentage of activities marked as Losses to be only 2% of the total changeover process as the greatest benefit. A graphical comparison of the changeover process duration of the previous state, the state after division the activities into internal and external ones, and the status after corrective measures has been implemented is shown in Figure 10 (green colour represent the duration of internal changeover activities (equipment idle time) and red represents external activities which are performed while the machine is running). A comprehensive evaluation of the proposed solutions aimed at improving the changeover process is based on a comparison of the previous changeover time and the changeover time after the implementation of all corrective measures. The changeover process time has been reduced from the original 848.6 s to 607.5 s. In the previous changeover process, all activities were performed during shutdown of the equipment, indicating that the changeover time was considered idle time.

5 Conclusions

In the production process, there are often activities that do not add any value to the product. The customer is not willing to pay for these activities and therefore it is necessary to eliminate them. To solve the problem, enterprises are implementing elements of lean manufacturing into the practice. Leaning of the enterprise's production process will reduce costs, increase utilization of production capacity, resources and improve economic results.

The effort to satisfy specific customer requirements cause variability in production, which has the effect on interrupting the continuous production process by changing the settings / adjustments of the machine. Due to the interruption of production, changeover can be considered waste. The mentioned waste cannot be completely excluded from the production process, therefore the authors of the paper focused on shortening its time duration by applying the SMED method.

Due to the size of the enterprise and the number of employees, small enterprises, or some medium-sized enterprises, usually do not invest into the elements of Industry 4.0 (alternatively only partially into selected activities), but gradually implement lean principles and methods. Especially for small enterprises, the fact is that many of them are not ready and able to manage the Industry 4.0 tools as an extension of the lean concept, because the lean concept itself is currently a challenge for them.

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LEANING OF PROCESSES AND IMPROVING THE WORKING CONDITIONS OF THE NEWLY CREATED WORKING ZONE

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Keywords: working conditions, working zone, layout, efficiency, lean
Abstract: The aim of the article is to propose ways to increase the functioning efficiency of the newly created workplace with regard to the course of the processes themselves, as well as of the working conditions of the affected employees in the selected company, dealing with the production of refrigeration and air conditioning units for automobiles. The automotive market is primarily customer-oriented, to which companies strive to meet and deliver high-quality products that are different from their competition. To ensure this goal, it is necessary to acquire theoretical knowledge in the field of organization and structure of the production process. It is also necessary to analyse problematic points of the newly created working zone on the basis of observations and interviews with employees. The essence of streamlining the workplace and improving the working conditions of employees lies in the identification, analysis and elimination of shortcomings, that have arisen mainly due to dynamic changes and rapid implementation of the working zone in the corner of the production hall. Based on the identified deficiencies, the authors of the paper have proposed corrective actions and have analysed the results of the improved condition.

1 Introduction

Adapting work and working conditions to a person is a necessity for the effective management and improvement of production processes. The company should provide such working environment for the employees that ensures work without endangering their health, without disturbing elements and unnecessary movements [1]. The efficiency of production from an economic point of view depends on appropriately selected production processes and optimal equipment, on the correct layout of the production system, on the quality of work performed, on prices, safety regulations, and technological procedures [2]. Maximum efficiency can be achieved only by reducing resource consumption while increasing production volume [3].

2 Description of the newly created workplace and its shortcomings

The newly created working zone of fluxing (application of the chemical substance flux on perfectly degreased aluminium semi-finished products) with an area of 312 m^2 is situated in a dispositionally separated area of the production hall. There is a machine inside it, through which three types of semi-finished aluminium products pass, all a part of air-conditioning and cooling units of cars and electric cars. The Paintflux device is used to apply a mixture of flux to perfectly degreased semi-finished aluminium products, which are assembled into a certain component and subsequently soldered in an electrically heated furnace at a high temperature of 615 °C. Since soldering technology is very prone to pores, cold joints, undercuts, erosions, and leaks between the individual components, it is necessary to apply flux in exact concentrations per m^2, which could only be achieved by purchasing the Paintflux machine, equipped with a nozzle on the robotic arm. At the workplace, there are also a measuring workplace, waste management, cabinets for personal belongings of employees, work aids, cleaning products, and collection tanks for dangerous waste located. Empty crates, crates with input material, and crates with output material also take up a large area of the workplace. Crates with input and output material are placed chaotically, without a precise system of inventory control and material flow. Like every new production process, it needs to be dynamically improved and systemically managed, precisely because of its initial shortcomings and the growing demands in the automotive industry.

The leanness of production lies in production without unnecessary components, with decreasing time, space, mistakes, and costs in production [4]. Lean philosophy become a very widespread approach to gaining high efficiency in production and logistics processes. The introduction of lean manufacturing has eliminated waste from non-products, excess processes, time losses, inefficient movement of materials and workers, surplus stocks and overproduction. It covers the entire value chain of business [5].

Due to the quick location of this zone in the corner of the production hall, without taking into account the working conditions of each season, material flow, waste management, and the impact of dangerous substance flux into the environment, it is necessary to optimize and systematically harmonize all these points to suit to the requirements of the standards of the automotive industry (OHSAS, ISO 14001, IATF 16 949, VDA6.3, 5STAR). The main impulse for solving the issue was non-compliance with daily production plans. The five employees of this workplace often had to work overtime, or employees from other departments helped them, or they had to also work on Saturdays. Therefore, it was necessary to shorten the daily time needed to flux all semi-finished products.

The need to effectively deal with the location of the workplace was necessary, as employees chaotically and in a disorganized manner managed the flow of material that did not meet the requirements. At the workplace, basic principles were missing for creating and maintaining an organized, clean, and high-powered 5S workplace. Due to the disorganized location of the workplace, semi-finished products were exchanged, which resulted in a loss of the form of unfulfilled daily production plans.

Layout is undoubtedly one of the most important tasks, because it has a direct impact not only on the company economy, but also affects safety at work and social environment of the company. Wrong allocation or layout of the productional and non- productional subjects, storage areas or distribution centres of the corporation can later cause huge problems. There are plenty of ways how to solve different problems with disposition and every single case usually has its own variables which are unique and different from other cases [6].

The creation of the layout itself - the spatial arrangement of the workplace - has a great impact on the overall efficiency of production. A properly designed layout reduces overall production time, eliminates unnecessary movements and transport of material, shortens unnecessary waiting, improves material flour, etc. The purpose is to arrange workstations, machines, equipment, and other necessary equipment so that employees work as efficiently as possible without much effort and unnecessary movements, which has an impact on production and transport costs [7].

One of the other serious shortcomings of the workplace was the direct contact of operators (Figure 1) with the chemical substance flux, which is harmful in direct contact. During the spread of flux to the ends of semi-finished products – manifolds, there was direct contact of the employee with the flux, because the nozzle of the machine could not apply the flux to semi-finished products at a 90° angle. The employee spread the flux by hand with a pressure vessel to the inner ends of the manifolds, with no barrier separating it from the flux aerosol. The employee responsibly used a gas mask and the prescribed protective for the given task. However, from a long-term perspective, a process such as this is ergonomically and safely unacceptable for workplace workers, as the flux enters the environment in the form of fine particles, which can cause health problems in long-term exposure.

Figure 1 Direct contact of operators with flux

The last significant negative aspect is standing work, as standing work in one place with the involvement of both upper limbs predominates among the employees of the workplace. The subsequent consequence of straining the musculoskeletal system of employees is back pain.

3 Methodology

After considering the theoretical knowledge, all shortcomings related to the Paintflux zone were revealed and analysed on the basis of observations and interviews with employees. Interviews with employees and observations were also the basis for streamlining the zone and for improving employees' working conditions.

It was also necessary to shorten the time needed to flux all required types of semi-finished products according to the daily needs of the customers – 716 minutes. Of this, the net production time needed to flux all models was 476 minutes. Non-production time was 240 minutes. The given times were calculated based on measurements of individual Cycle times, where the volume of individual semi-finished products loaded in one minute was measured with a stopwatch.

Cycle time is the time starting when operation begins to the point of time when the operation ends. Cycle time should be considered as a viable option, when an organization is trying to improve efficiency, cost base and customer responsive [8].

Cycle time reduction is of paramount importance in a manufacturing industry as the customer not only emphasizes the quality of the products, but also takes into consideration its timely delivery [9].

The times of the individual activities are shown in Table 1.

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Table 1 Calculations of equipment utilization during one work shift

Paintflux - list of semi - finished products			Daily requirement	Length of frame/semi - finished product (mm)	Gap between frames	Number of products on the frame/belt	Gap + frame (mm)	Paint flux conveyor (mm/min)	Time needed (min)	number/ min	Real needed time
BC	J1	ASSY MANIFOLD-B/C D16 X 1 F	70	400	100	30	500	1720	2,1	33	6,36
	J1	ASSY MANIFOLD-B/C & D16 X 1 A	70	400	100	30	500	1720	2,1	33	6,36
	J1	ASSY MANIFOLD-B/C D16 X 1 C	70	400	100	30	500	1720	2,1	33	6,36
	J1	ASSY MANIFOLD-B/C D10 X 1 B	140	400	100	30	500	1720	4,2	33	12,73
	J1	MANIFOLD-B/C D16 X 1 E	70	400	100	30	500	1720	2,1	33	6,36
	J1	ASSY MANIFOLD-B/C D16 X 1 D	70	400	100	30	500	1720	2,1	33	6,36
	J1	ASSY MANIFOLD-B/C & D10 X 1 A	70	400	100	30	500	1720	2,1	33	6,36
	BEV 2013	MANIFOLD ASSY DIRECT CHANGE / RETURN	408	400	100	15	500	1720	14,6	28	43,71
	BEV 2013	MANIFOLD ASSY INLET OUTLET	408	400	100	15	500	1720	14,6	28	43,71
	SP12	MANIFOLD - INLET/OUTLET 1M C	840	400	100	30	500	1720	20,0	42	60,00
		MANIFOLD - RETURN 1M C	840	400	100	30	500	1720	20,0	42	60,00
	SP05 Lower	MANIFOLD - INLET/OUTLET 2M B	165	400	100	15	500	1720	5,9	28	17,68
		MANIFOLD - RETURN 2M B	165	400	100	15	500	1720	5,9	28	17,68
	SP05 Upper	MANIFOLD - INLET/OUTLET 3M D	165	400	100	15	500	1720	5,9	28	17,68
		MANIFOLD - RETURN 3M D	165	400	100	15	500	1720	5,9	28	17,68
CAC	CAC 992	HEADER - INTERCOOLER	560	290	50	10	340	1720	9,3	60	9,3
	Panther CAC	HEADER - INTERCOOLER	2600	170	50	10	220	1720	37,1	70	37,1
	HDT6 CAC	HEADER - INTERCOOLER	240	210	50	7	260	1720	4,1	58	4,1
	Macan F/L	HEADER - INTERCOOLER	800	300	50	10	350	1720	13,3	60	13,3
RAD /LTR	C519 (Ilava 3)	HEDER-RAD CORE INLET 14mm	1520	510	50	10	560	1720	38,0	40	38,0
		HEDER-RAD CORE INLET 18,5mm	1120	510	50	10	560	1720	28,0	40	28,0
		HEDER-RAD CORE INLET C2 LTR 25,25mm	660	510	50	10	560	1720	16,5	40	16,5
change		2 times/1 work shift							20		
starting time									60		
shift cleaning									60		
end day cleaning									50		
break time									50		
	Time required to cover the required volumes								715,4		

Other necessary data for the calculation were the length of the frames which the semi-finished products are stored on, the gap between the frames, the number of products on the frame, conveyor belt speed, the time required to start the machine into operation, the time required to clean the machine during operation, the time required to clean the machine work change, time required to change the model and break time. The only constant statement for all types of semi-finished products was the speed of the belt, which moved at a speed of 1720 mm/min.

The time required to start the machine – **starting time** – includes switching on, starting up, and stabilizing the machine. This time includes heating the machine to a working temperature of approx. 300 ° C, preparing the semi-finished products according to the production plan on a given day, preparing and marking the crates, writing daily verification forms, mixing and filling the flux into the machine, and verifying production before starting.

The time required to clean the machine during shift work – **shift cleaning time** – includes cleaning the nozzles and flux circuits of the machine.

The time required to clean the machine after the work shift – **end day cleaning** – includes the complete cleaning of the flux chamber, circuits, and ducts for the wastewater outlet from residual flux and other impurities.

Based on the stated information and in accordance to terms of the time horizon of one work shift, it was not possible to cover the given volume.

4 Results of the improved working conditions

Each production company must determine its goals individually, so that they correspond to the organizational structure of the company. In order to ensure the main goals of the company, it is also necessary to determine partial goals, which include, for example, minimizing costs or maximizing the use of corporate capacity. The goals that the company sets itself are achieved by eliminating waste in production processes [10].

The issue of the working zone layout was resolved by a new workplace layout, which was necessary to create to eliminate unnecessary movements that operators had made while picking input material, placing manifolds on frames, pre-production, removing final products from the machine conveyor belt, etc. The layout (Figure 2) was designed to ensure simplest possible work for employees, and at the same time, making the workplace safe.

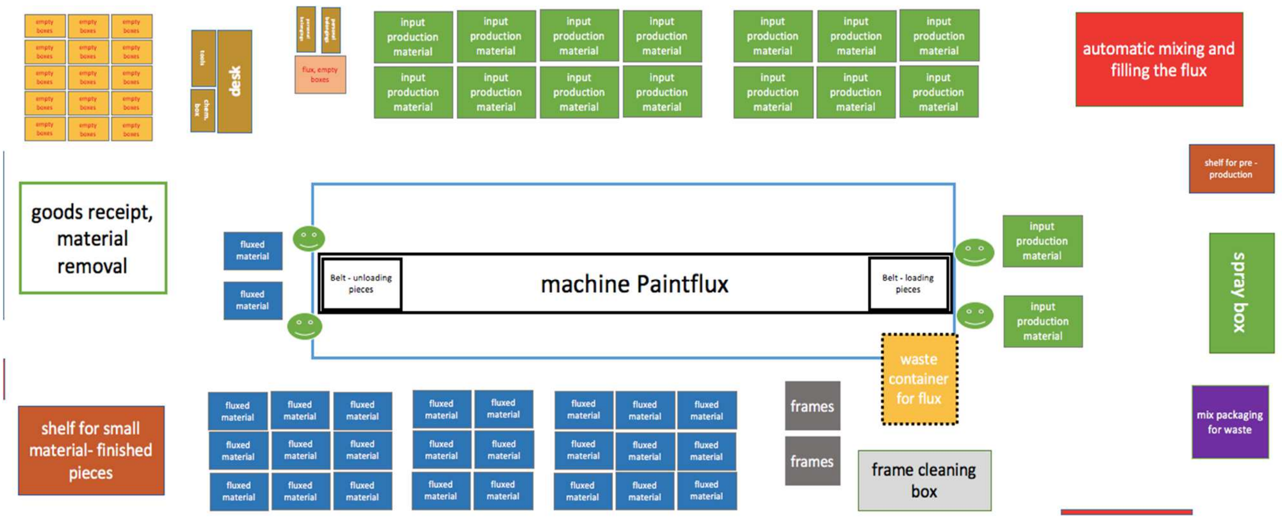

Figure 2 New workplace layout

Figure 3 shows the material flow from the intake to the workplace to the removal of finished pieces by the line feeder for further processing.

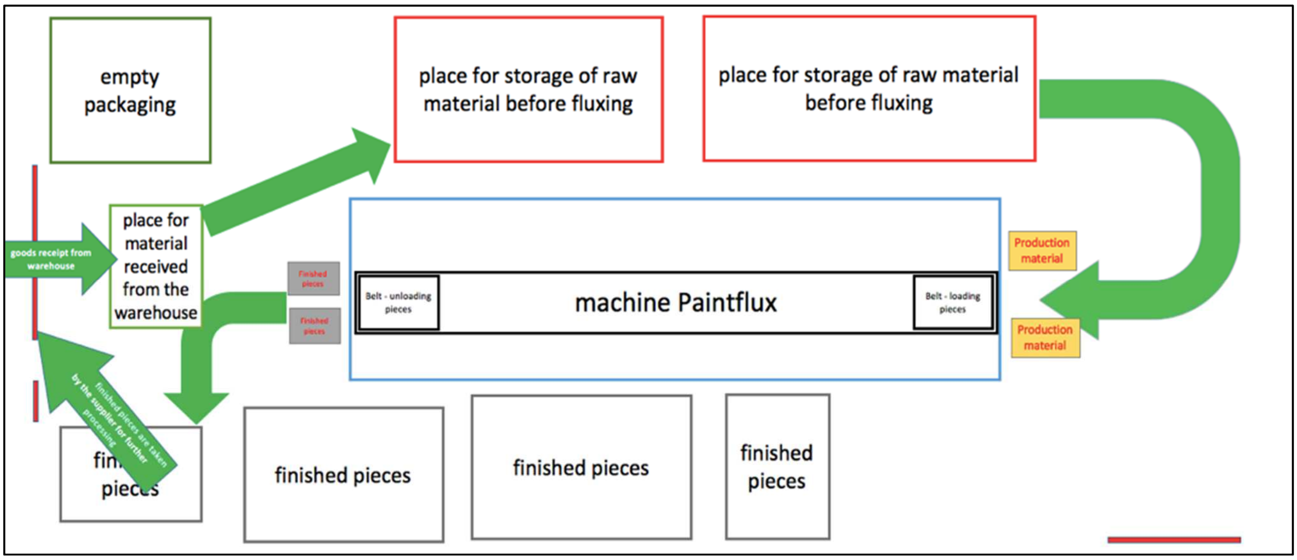

Figure 3 Material flow in the workplace

To ensure daily production plans, it was also necessary to focus on all operations that were not related to the creation of added value. With simple improvements, it was possible to reduce the utilization of the device during one work shift to 411 minutes (Table 2). Net production time was 365.7 minutes from the original 476 minutes. Net production time was eliminated because the manifolds pass through the machine two times. Originally, they had to go through the machine three times for perfect fluxing of circular semi-finished products, but by simply placing manifolds on the frames, employees will now achieve perfect fluxing in less time. This leaning saved approximately 110 minutes. Reduced activities, which originally took 240 minutes, were eliminated by leaning individual activities to 45 minutes.

Table 2 Calculations of equipment utilization during one work shift after streamlining the production process

Paintflux - list of semi - finished products			Daily requirement	Length of frame/semi - finished product (mm)	Gap between frames	Number of products on the frame/belt	Gap + frame (mm)	Paint flux conveyor (mm/min)	Time needed (min)	number/ min	Real needed time
BC	J1	ASSY MANIFOLD-B/C D16 X 1 F	70	400	100	30	500	1720	2,1	33	4,24
	J1	ASSY MANIFOLD-B/C & D16 X 1 A	70	400	100	30	500	1720	2,1	33	4,24
	J1	ASSY MANIFOLD-B/C D16 X 1 C	70	400	100	30	500	1720	2,1	33	4,24
	J1	ASSY MANIFOLD-B/C D10 X 1 B	140	400	100	30	500	1720	4,2	33	8,48
	J1	MANIFOLD-B/C D16 X 1 E	70	400	100	30	500	1720	2,1	33	4,24
	J1	ASSY MANIFOLD-B/C D16 X 1 D	70	400	100	30	500	1720	2,1	33	4,24
	J1	ASSY MANIFOLD-B/C & D10 X 1 A	70	400	100	30	500	1720	2,1	33	4,24
	BEV 2013	MANIFOLD ASSY DIRECT CHANGE / RETURN	408	400	100	15	500	1720	14,6	28	29,14
	BEV 2013	MANIFOLD ASSY INLET OUTLET	408	400	100	15	500	1720	14,6	28	29,14
	SP12	MANIFOLD - INLET/OUTLET 1M C	840	400	100	30	500	1720	20,0	42	40,00
		MANIFOLD - RETURN 1M C	840	400	100	30	500	1720	20,0	42	40,00
	SP05 Lower	MANIFOLD - INLET/OUTLET 2M B	165	400	100	15	500	1720	5,9	28	11,79
		MANIFOLD - RETURN 2M B	165	400	100	15	500	1720	5,9	28	11,79
	SP05 Upper	MANIFOLD - INLET/OUTLET 3M D	165	400	100	15	500	1720	5,9	28	11,79
		MANIFOLD - RETURN 3M D	165	400	100	15	500	1720	5,9	28	11,79
CAC	CAC 992	HEADER - INTERCOOLER	560	290	50	10	340	1720	9,3	60	9,3
	Panther CAC	HEADER - INTERCOOLER	2600	170	50	10	220	1720	37,1	70	37,1
	HDT6 CAC	HEADER - INTERCOOLER	240	210	50	7	260	1720	4,1	58	4,1
	Macan F/L	HEADER - INTERCOOLER	800	300	50	10	350	1720	13,3	60	13,3
RAD /LTR	C519 (Ilava 3)	HEDER-RAD CORE INLET 14mm	1520	510	50	10	560	1720	38,0	40	38,0
		HEDER-RAD CORE INLET 18,5mm	1120	510	50	10	560	1720	28,0	40	28,0
		HEDER-RAD CORE INLET C2 LTR 25,25mm	660	510	50	10	560	1720	16,5	40	16,5
change		2 times/1 work shift							10		
starting time									15		
shift cleaning									0		
end day cleaning									20		
break time									0		
	Time required to cover the required volumes								410,7		

The time required to start the machine was reduced from 60 minutes to 15 minutes by completely removing the warmup of the machine. The waiting was eliminated by having retrained the masters of the other departments to put the Paintflux machine into operation. Every day, during the night shift, the production master now switches on the Paintflux machine about an hour and a half before the morning shift, which is then ready and heated when employees arrive at the workplace.

The time required to clean the machine during shift work was reduced from 60 minutes to 0 minutes by setting aside an adjuster, that ensures that the Paintflux machine runs continuously. The adjuster manually cleans the nozzle of solid and settled residue (exchange for another) during the work of the operators, so there is no need to interrupt production. The flux circuits are cleaned as the model is changing when the gap on the belt between the previous – ending model and the next model is sufficient enough not to affect the adjustment time.

The time required to clean the machine after the work shift was reduced from 50 minutes to 20 minutes by removing the excess cleaning of certain parts of the machine from the automatic cleaning cycle.

The model change time was reduced from 2×10 minutes to 2×5 minutes so that employees do not empty the machine conveyor belt when the model is changing. Before improving this operation, the belt was allowed to empty due to the separation of defective parts (poor flux concentration), and therefore this change took about 10 minutes. From experience of the operators, it was clear that poor flux concentrations are very rare, and therefore other pieces can be loaded immediately after the calibration plates, where you do not have to wait for the belt to be emptied; this replacement only takes 5 minutes. If the flux concentration on the semi-finished product is incorrect (nozzle clogging), operators are trained to suspend the suspicious dose by separating it from the good pieces and adjusting the flux concentration (the flux concentration can be up to three times higher but cannot be lower).

The break time was reduced from 50 minutes to 0 minutes by alternating between five workplace employees for breaks, which allows the machine to produce continuously.

After quantifying the recoverability of the equipment and leaning the production process, it is clear that there is approximately 69 minutes of networking time left, which is used by the employees for pre-supply of the finished products. The pre-supply is produced operatively, which means that the company maintains approximately two days of pre-supplying the parts needed for the next two weekends. These supplies must be available, for example, in the event of a failure of the machine or the individual equipment required for fluxing.

Employees try to prevent possible failures by preventive daily maintenance, regular cleaning, and predictive replacement of sensitive parts with new ones. Sensitive parts are replaced twice a year, before summer and winter shutdowns. Sensitive parts are, for example, membranes on compressors, hoses, V-belts, and so on.

To eliminate the already mentioned direct contact of the flux with employees, a spray box was purchased for the workplace. It is a closed space of 2×2 meters, where the flux is applied with a pressure gun to the inner ends of semi-finished products. The method of applying flux in a spray box consists of manually applying a flux layer by a spray nozzle identical to the nozzle in the flux chamber of the machine, except for those product areas which are not available for flux in the machine chamber. The operator takes the required number of products, puts them inside the box on a turntable, then applies the flux to each side and lets them dry for about two hours. Operators are protected this way from the flux aerosol, which used to be dispersed into the space around them by manually applying flux to the inner ends of the manifolds. The spray box and its method of spraying are shown in the following Figures 4 and Figure 5.

Figure 4 Spray box

Figure 5 Method of spraying in the box

When designing the machine for manual flux application, it was necessary to ensure impermeable isolation of the interior spaces from the external working environment of the employees. After installing the machine at the workplace, it fulfilled its purpose. The flux is now poured by the operators into a pressure vessel located next to the machine, from which the flux is then automatically delivered to the spray gun, by which the application of the flux is applied to the product pieces. This machine also ensures the extraction of the generated steams which accumulate inside the machine into a chimney. Before putting the machine into operation, the accredited health services checked its emissions released into the air outside the company. These emissions were values that were within the allowable limit of 0,3 times (98 mg*m-3 in 160 minutes) the allowable limit, so they do not pose a risk to human activity.

As standing work in one place predominates at this workplace, it was necessary to solve the impact of such work on the musculoskeletal system of employees. During an interview with the employees of the given workplace, it was found out that the pain in their spine and hip joints persisted.

Standing work, together with sitting work, is the most common working position, in which various problems of the motional system arise. It is not only because one's own posture, but mainly to the way a person stands and how long they stand in that given position. The basic position of the production line operator is just working in a standing position, where a larger range of motion expanding higher muscle strength is required. When standing, most of the weight is transferred to the lower limbs. If the work allows it, it is ideal to alternate standing work with sitting work and change stereotypical positions that have a negative impact on human health [11].

This health risk has been reduced by the provision and use of ergonomic anti-fatigue mats (Figure 6) in the standardized size of 600×1200 mm, which is available to every worker in the workplace performing long-term work while standing. Anti-fatigue mats eliminate the danger associated with working in one place.

Figure 6 Application of anti-fatigue mats to the workplace

After the implementation of all proposed and approved changes, significant time savings were achieved, which are shown in yellow in Figure 7 below. The red colour represents the duration of the activity in minutes before improvement, and the green colour after improvement. Numbers from 1 to 8 on the vertical axis represent individual work activities: 1 – the time required to influx the daily demand of the manifolds (TA), 2 – the time required to influx the daily demand of CAC headers (TA), 3 – the time required to influx the daily demand of RAD headers (TA), 4 – model exchange (TB), 5 – starting time (TB), 6 – shift cleaning time (TB), 7 – end day cleaning time (TB), 8 – breaks (TC).

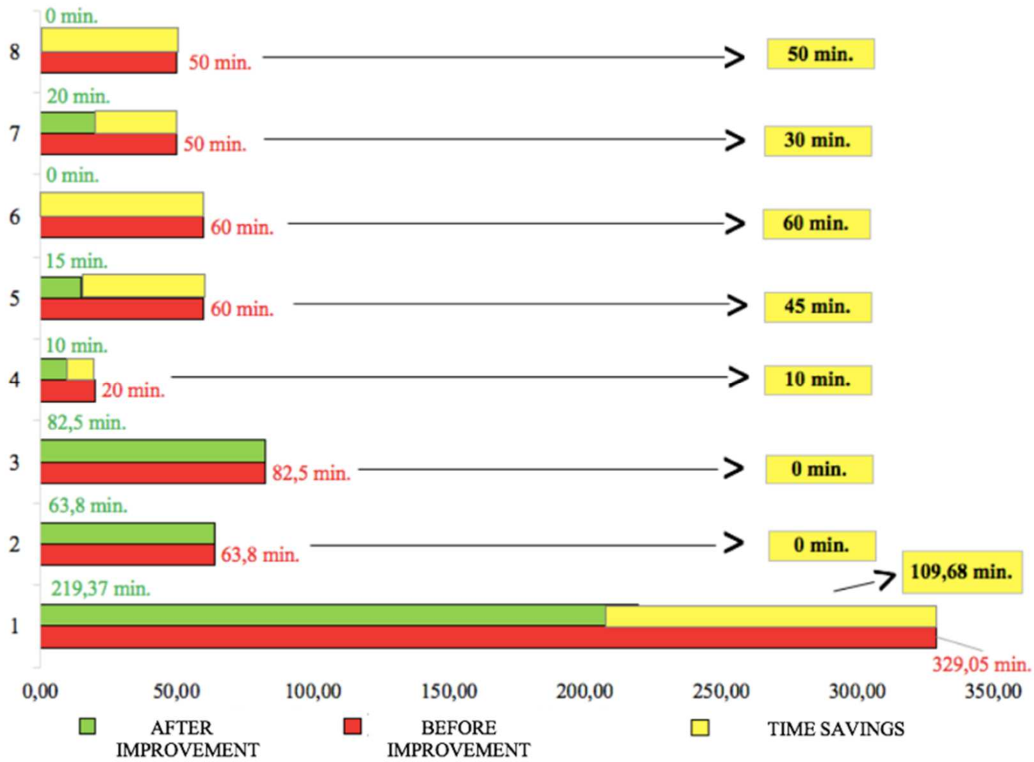

Figure 7 Time savings

From Figure 7, it is possible to read the individual time savings, which together after rounding represent a time of 305 minutes. This time saving ensured that all customer requirements were met while working on one work shift. Also, the new layout gave the workplace a more organized look that suits the 5S standards. The new arrangement must be look after by employees, especially for their safety at work. The layout also meets the necessary standards for material placement and flow (FIFO inventory management system).

After procuring a closed spray box, the problem of direct contact of employees with the chemical flux, which was dispersed in the form of fine particles into the working environment during manual spraying, was also effectively solved.

5 Conclusions

At present, it is a very common phenomenon in organizations to use new tendencies in production processes and their management. It is mainly about increasing customer requirements for quality, shortening delivery times, enforcing market conditions, and product variability. To meet all these aspects, organizations must reduce their downtime, apply new production technologies, and reduce inventory by shortening lead times [12].

Streamlining - lean production and its principles cannot be understood as an exactly defined and closed system. Lean production implementation is most often a reaction to a certain type of problem at a given company. Many lean production ideas originally came from the automotive industry. Lean production makes it possible to achieve the required level of the production system and increase production efficiency accordingly. In countries that have achieved an advanced level of development, the concept of lean manufacturing is recognized as an industrial development strategy that enables market leadership to be achieved. However, as these principles have been gradually developing and expanding to other industrial areas, other methods and instruments have been added and used for improving processes [13-17].

The need to improve the production process in the newly created working zone was based mainly on the need to meet specific customer requirements, and to process semi-finished products in the highest possible quality at reasonable costs. Due to the unreasonable and quick allocation of the workplace in the corner of the production hall, various negative facts came to light over time, which needed to be improved or eliminated.

The workplace modification fulfils the volume requirements of customers after all. After the implementation of all ideas and improvements, compliance with all internal requirements was achieved, including the principle of continuous improvements Kaizen, FIFO inventory management system, and requirements for individual standards such as IATF 16949, ISO 14001, ISO 18000, OHSAS.

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INNOVATIVE APPROACHES TO ASSESSING ORGANIZATIONAL CHANGES AT AUTOMOTIVE INDUSTRY ENTERPRISES: THE EU EXPERIENCE FOR UKRAINE

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Keywords: organizational changes, innovations, corporate management, automotive industry
Abstract: The article considers the features of organizational changes (organizational innovations) that have been carried out in the automotive industry of countries that have relatively recently joined the European Union (the Czech Republic, Slovakia, Poland, and Romania). These countries, starting from 1990s and throughout 2000s, rebuilt their own automotive industry and managed to attract investors, which resulted in increased production and car exports. The article substantiates that in the modern world the automotive industry has tendencies towards internationalization (production in different countries), development of large multi-brand concerns (production of different classes and makes of cars), cooperation (OEM companies and car dealers cooperating with concerns), and specialization (each country produces cars that meet market needs, either for domestic consumption or for export). This issue is extremely important for Ukraine, as the Ukrainian automobile industry now ranks second among the post-Soviet countries and 11th among the Eurozone countries in terms of production, with 7 automobile plants operating in Ukraine. The purpose of the article is to analyse organizational changes in the automotive industry enterprises in Eastern Europe, including the introduction of innovations, as well as to determine the possibility of implementing such changes in the automotive industry in Ukraine.

1 Introduction

The relevance of the stated research topic is quite high. Organizational changes are those processes that accompany business and are necessary for overcoming the crisis, increasing competitiveness, and reaching a new level of development. As noted by Mescon, Albert and Khedouri, organizational changes are “management’s decisions to change one or more of the internal variables: organizational goals, structure, objectives, technology, and the human factor” [1]. Organizational changes help to overcome the negative impact of external factors or increase the positive impact of positive external factors. The main thing is to choose the right strategy in these conditions. This is also relevant for the Ukrainian automobile industry, which now ranks second in the post-Soviet space and 11th in Europe in terms of production, with 7 automobile plants operating in Ukraine. However, by 2018 car production in the country decreased by 90 times compared to 2008, and continues to decline, while only 2% of the car plants capacity is used [2]. This is related to the new environmental standards for Euro-5 cars, signing of the free trade agreement between Ukraine and the European Union in 2014, and the growth of foreign car imports into the country. All this makes the need for changes in the automotive industry of Ukraine extremely urgent, and these changes need to take into account the experience of countries that have recently joined the European Union (the Czech Republic, Slovakia, Poland, and Romania). This is what the Article discusses.

The purpose of the study is to analyse organizational changes in the automotive industry enterprises in Eastern Europe, including the introduction of innovations, as well as to determine the possibility of implementing such changes in the automotive industry in Ukraine.

2 Literature review

In the research literature on management the issue of organizational change and management of organizational change at enterprises is considered quite often. As mentioned earlier, Mescon [1] and co-authors see organizational changes in the fact that companies alter certain parameters of their activities in response to external threats or for maintaining external opportunities (Figure 1):

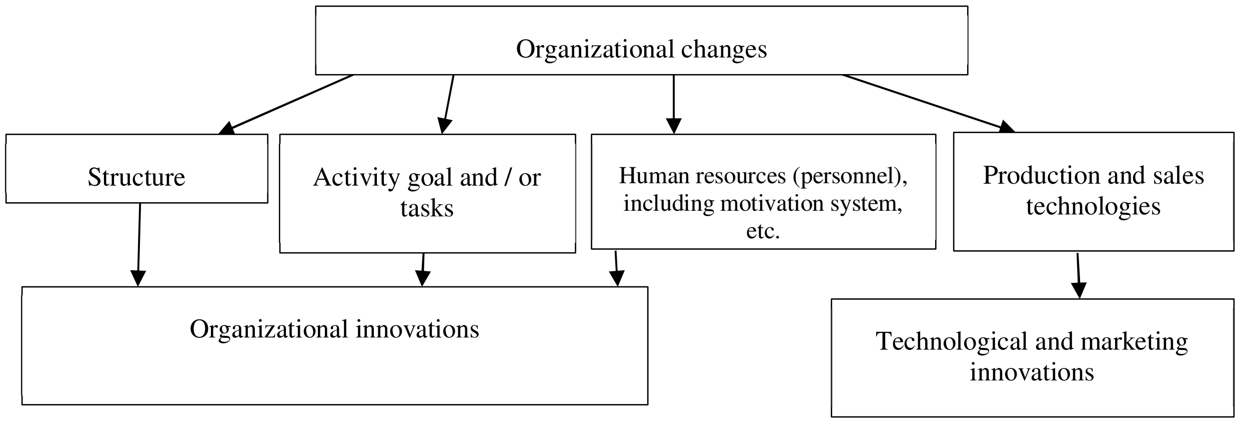

Figure 1 Directions of organizational change

In other words, organizational changes lie precisely in the introduction of innovations - organizational, which include changes in strategy, structure, personnel and personnel management, or technological, when new technologies are introduced, especially in production and sales. This is indicated, for example, by Bykov and co-authors [3], Grigoryan [4] and Goncharov [5]. Changes in the organization can look like development cycles (from birth to formation, growth, and aging), evolution (from birth to growth through selection in competition), or dialectics (when there is a conflict associated with changes in the environment, and changes are the response to this conflict and will bring or will not be able to bring the organization to a new level). This is noted by Wybrańczyk and co-authors [6]. It is completely clear that for existing large enterprises operating in the automotive industry, it is the "dialectical" changes that are most relevant.

Current trends in the development of the automotive industry, especially in Eastern Europe, but also the world as a whole, are described by such authors as Vozmilova and Volgina [7], Terekhov [8], Schwartz [9], Łuczak and Małys [10], Menes [11] and L. Mytna Kurekova [12].

Global trends, which are noted by such authors as Łuczak and Małys [10], include:

- changes in customer demand (taking into account safety, comfort, fuel savings and environmental friendliness);
- diversification of demand by different types of cars: for premium makes, which include Audi, Mercedes, BMW, Lexus, Infiniti, and Volvo, as well as some makes that are produced in the luxury segment, and for mass makes that are available to a large number of potential buyers;
- development of new items for the automotive industry and demand for them (multimedia systems, communication, navigation, trip automation);
- growth of environmental requirements from the state [10].

All of the above encourage changes in the structure of automobile production. OEM-type enterprises ("original equipment manufacturer" - a company that produces parts and equipment that are sold to automakers under their brand name) open up. The development of those divisions of automobile companies engaged in R&D is becoming important [10].

In terms of meeting demand in different market segments, modern car companies are diversifying production, producing different makes at the same time, for example,

- Volkswagen Auto Group includes several companies that produce different types of cars for various purposes; makes that belong to the concern include Volkswagen, Audi, Škoda, Seat, Bentley, Bugatti, Ducati, Lamborghini, Porsche, MAN, Scania (although there are separate companies for each make, they are quite large car concerns, such as Audi Group);
- PSA group: Peugeot, Citroen, DS, Opel;
- Toyota Motor Corporation: Toyota, Lexus;
- Hyundai Motor Group: Hyundai, Kia;
- FCA: Fiat, Chrysler, Alfa Romeo, Abarth, Maserati, Dodge, Jeep;
- Renault-Nissan-Mitsubishi Alliance (previously Renault-Nissan Alliance 1999-2017): Renault, Nissan, Mitsubishi;
- TATA: TATA, Jaguar, Land Rover;
- Daimler AG: Mercedes, Smart, Maybach;
- BMW Group: BMW, MINI, Rolls Royce [13].

These companies open operations in different countries simultaneously, leaving R&D units mainly in the country where the parent company is located. At the same time, they cooperate with independent OEM companies for the supply of original (licensed) components for cars (many of such companies operate in Southeast Asia, especially in

China) [15,16]. Based on the results of 2019, the world leaders are Toyota (10.86% of the market), Volkswagen Group (10.77%), Hyundai (7.49%), GM (7.11%), and Ford (6.63%) [14].

The modern structure of an automobile concern can be described by the following scheme (Figure 2).

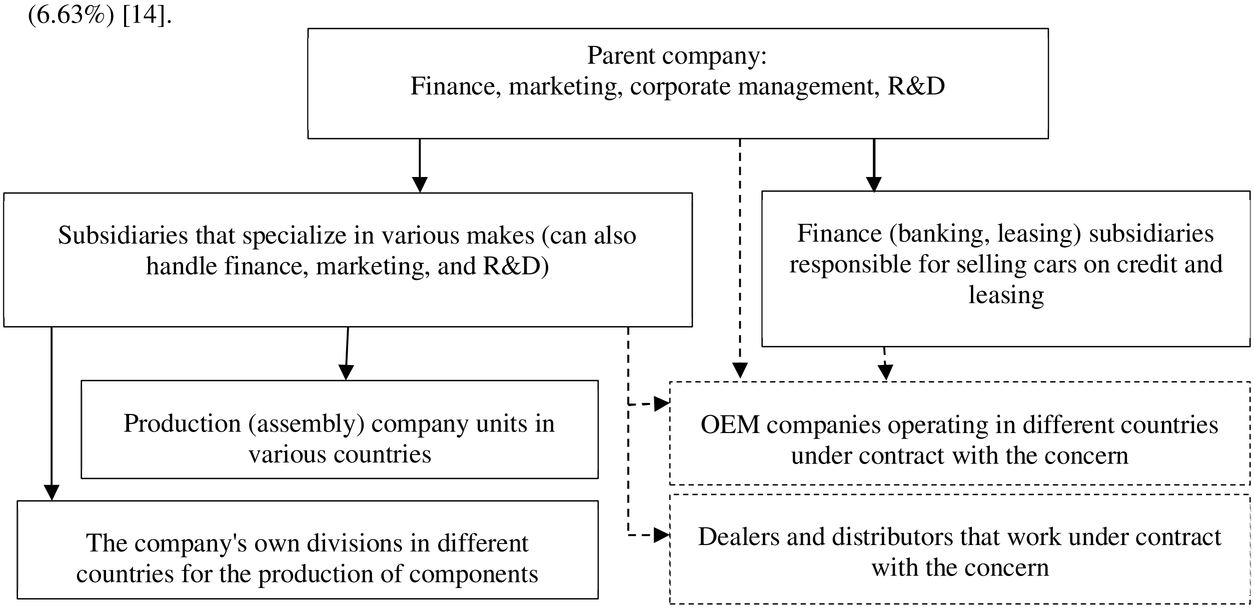

Figure 2 Modern structure of an automobile concern

In other words, a large automaker manages not only smaller "branded" companies (for example, like Volkswagen AG manages Audi and Škoda), but also creates financial divisions for lending and leasing, and works with independent OEM companies and with dealer companies and distributors. A concern is building an international business, which includes several elements. Some of them are directly controlled by the parent company, others are carried out under contracts. That is, the division of labour by areas (R & D, components, car assembly, sales) and the distribution of production by country is a current trend for global automakers. One feature of modern automotive business is the emergence of leaders in production and consumption from around the world.

For instance, 28.02% of cars are produced and 29.02% are used in China, 19.32% of cars are produced and 12.5% are used in the European Union (leaders - Germany, Spain and France, the Czech Republic is in the fourth place), in the USA 11.85% of cars are made and 19.80% are used, in Japan 10.55% of cars are made and 5.85% are used [14]. This is what determines the export orientation of enterprises in the industry, or the focus on the domestic consumer, or the growth of imports into the country.

Those authors who considered peculiar features of the development of the automotive market in Eastern Europe, such as Menes [11], Mytna Kurekova [12], Vozmilova, Volgina [7], point out that after joining the European Union, automotive products of these countries under their own brands were not competitive. Škoda was an exception, however, it was later purchased by Volkswagen). At the same time, the pressure on the car market in Eastern Europe is exerted by the import of cars, not only of the new makes, but also used cars (for example, 70% of cars imported to Poland from other EU countries in 2019 were used cars, and they were imported duty free PZPM, 2020 [17]. As it has already been mentioned, this trend is also relevant for Ukraine. That is why the authors note that the automobile production in Eastern Europe in many aspects involves deep specialization and export orientation (for example, the production of Volkswagen commercial vehicles in Poland), or the production of mass inexpensive car makes (Škoda in the Czech Republic, Fiat in Poland, Renault Dacia in Romania), Volkswagen, Kia, Peugeot and Citroen in Slovakia (although the country also produces the Land Rover luxury car) [9]. These countries, therefore, participate in the global division of labour, they house both assembly plants of large concerns and OEMs. At the same time, assembly plants specialize in certain makes and areas (in the economy segment, in the commercial segment).

3 Methodology

Qualitative and quantitative methods must be used to assess the organizational changes made in the automotive industry in Europe. The analysis includes four EU countries that have relatively recently joined the European Union and restructured their industry (Slovakia, Poland, Romania, and the Czech Republic).

Quantitative methods help to understand how the automotive industry of each country has changed: the volume of cars produced and the dynamics (growth rate). It is advisable to consider the dynamics until 2000, until 2004 (the countries in question, except Romania, joined the European Union that year), and until 2010 (last 10 years).

The International Organization of Motor Vehicle Manufacturers is the main source of data for quantitative analysis, as it provides information on car production by country and region for each year [14].

Qualitative methods are associated with the study of data in publications on which companies in the automotive industry operate in the countries in question, and which organizational changes have been made in these enterprises in recent years. The sites of automobile enterprises as well as other publications in open sources were used for the analysis. Methods of analysis and synthesis of the received information are applied.

4 Results and discussion

First, on the basis of statistical information, it is necessary to compare the volume of car production in Eastern European countries integrated into the European Union (Slovakia, Poland, Romania, and the Czech Republic) with the volume of production in Ukraine.

Figure 3 shows the change in production volumes of all types of cars in Slovakia, Poland, Romania, and the Czech Republic in 2000-2019.

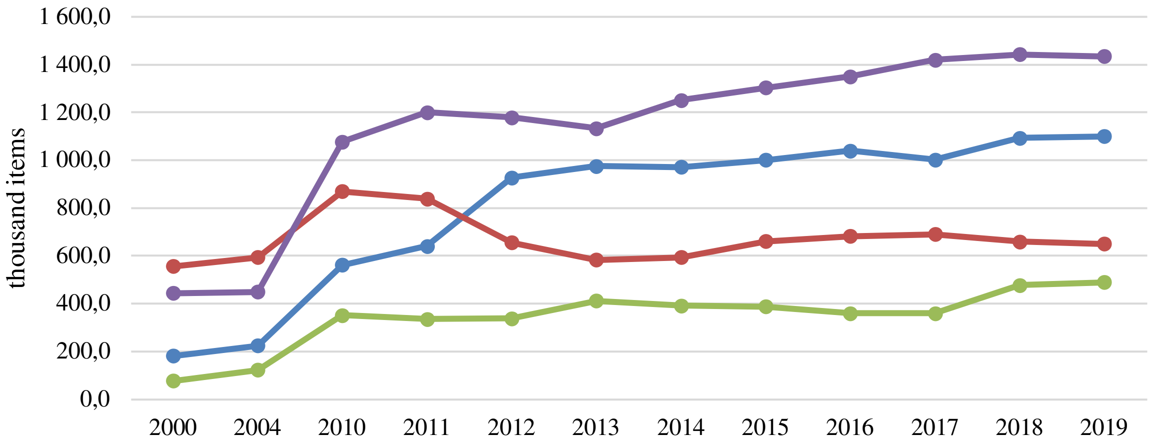

Figure 3 Production of all types of cars in Slovakia, Poland, Romania, and the Czech Republic in 2000-2019

As it can be seen from the presented data, in comparison with 2000 and 2004 (integration with the European Union, although for Romania it was 2007), all of the represented countries increased car production, the Czech Republic and Slovakia to a greater extent.

In 2019, the volume of car production in the Czech Republic was 8.09% of production in the European Union, in Slovakia - 6.20%. Among the countries of Eastern Europe that are members of the European Union, this comes to 32.8% and 25.16%, respectively [14].

The change in car production for Ukraine during the same period was quite different (Figure 4):

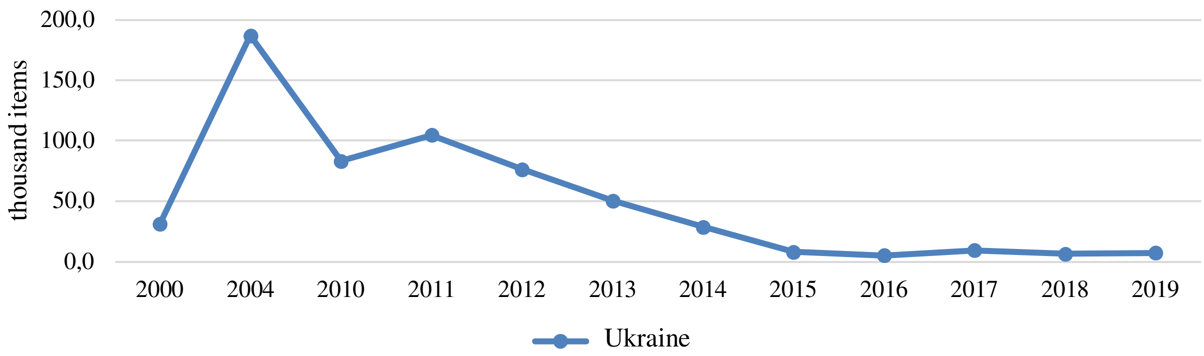

Figure 4 The volume of production of all types of cars in Ukraine in 2000-2019

From the presented data it is possible to note considerable decrease in the volume of car production from 2004 to 2010 and from 2012 to 2019. Table 1 presents the indicators of the dynamics of car production by country, including comparison with global and European dynamics.

Table 1 Indicators of the dynamics of car production by country in comparison with global and European dynamics (growth rate, %)

Country	2019 until 2000	2019 until 2004	2019 until 2010
Slovakia	605.7%	492.2%	195.8%
Poland	116.8%	109.4%	74.7%
Romania	627.1%	401.3%	139.8%
The Czech Republic	321.9%	319.8%	133.2%
The European Union	103.5%	96.8%	104.1%
Ukraine	23.2%	3.9%	8.7%
World	157.5%	143.0%	118.3%

The table shows that Slovakia has had the highest growth rate in the automotive industry since 2000, 2004 and in the last 10 years. Romania is in the second place in terms of growth, and since 2000 its automotive industry has been growing even faster than in Slovakia. The Czech Republic is in the third place. These growth rates are much higher than those across the European Union, and even around the world. In Poland, the dynamics of the automotive industry development is much lower, and in the past 10 years it has even decreased by 25.3% but increased since 2004 by 9.4% (which is higher than in the European Union as a whole).

Ukraine has significantly reduced the volume of car production (by 76.8% compared to 2000, by 96.1% compared to 2004, and even by 91.3% over the past 10 years). The reasons for the decline in car production in Ukraine are the reduction in exports to Russia (formerly the largest consumer of the Ukrainian automotive industry) and duty-free import of new and used cars from the European Union, which has reduced the competitiveness of Ukrainian cars and reduced demand in recent years [2].

Based on information in research articles and statistical information, automotive companies operating in Eastern European countries such as Slovakia, Poland, Romania and the Czech Republic as well as the history of organizational changes associated with those companies in recent years, after integration with the European Union are presented in the tables below.

Table 2 presents the main automotive companies in Slovakia and the history of organizational change in these companies.

Table 2 Enterprises of the automotive industry in Slovakia, and their history of organizational changes

Enterprise	Modern features	Implemented organizational changes
Volkswagen (Bratislava)	Produces small cars: VW Up, Škoda Citigo, SEAT Mii. Produces SUVs: Volkswagen Touareg, Audi Q7, Porsche Cayenne.	Originally a BAZ company (with the production of some Škoda models), it was bought by Volkswagen AG in 1991, re-equipped, and enlarged to produce other models. Shops for the production of components were opened. Logistics (delivery and distribution) is fully transferred to DHL. Gradually, from part of the work on the car production (the rest to be completed in Germany), it moved to a full cycle, to the production of finished cars.
PSA Peugeot Citroen (Trnava)	Specializes in 3 makes: Peugeot 207, Citroën C3 Picasso, Peugeot 208.	Opened as a new PSA Peugeot Citroën plant in 2003 (with business processes developed at the parent company), with the production of bodies (including stamping and welding), and assembly. Since 2011, the plant has increased production capacity and now has 3,500 employees.
Kia Motors (Žilina)	Specializes in 2 makes: Kia Cee'd, Kia Sportage.	Opened in 2007 as a new enterprise of the Kia concern in Žilina (2800 employees), with modern equipment that can produce up to 8 models on one line.
Jaguar Land Rover (Himpa)	Specializes in 2 makes: Land Rover Discovery i Land Rover Defender.	Opened in 2018 in Bratislava, at once as a fairly large enterprise with 1,500 employees, with modern equipment and business processes that have been developed by the parent company.

That is, in addition to Volkswagen Bratislava (the largest automotive company), others were founded as new companies, which immediately "adopted" the processes developed in the parent companies. Only Volkswagen had to significantly restructure the processes at the old plants. Table 3 presents the main automotive companies in Poland and the history of organizational change in these companies.

Table 3 Enterprises of the automotive industry in Poland, the history of organizational changes

Enterprise	Modern features	Implemented organizational changes
Fiat Auto Polska / FCA	Produces 39.91% of all cars made in Poland in 2019; specializes in mass makes of Fiat: Fiat Seicento (Fiat 600), Fiat 500, Fiat Panda. They are produced both for export and domestic use.	Created during the acquisition of Polish FSM plants by Fiat (1993). Only a few plants, where the re-equipment of production was made, retained the production (assembly) of cars. Others switched to the production of components.
Opel Polska (GM Poland)	Produces 16.39% of all cars manufactured in Poland in 2019; specializes in Opel Astra J hatchback and Opel Cascada brands.	Originally opened as a GM plant in Poland in 1998, it initially specialized only in certain mass-produced cars (assembly only). At the plant in Gliwice in the 2000s, with the growth of production capacity, modern production systems were introduced: Just-in-time, Just-in-sequence.
Volkswagen Poznań	Produces 41.05% of all cars made in 2019 in Poland; specializes in commercial vehicles, primarily VW Caddy and VW Transporter, majority of the cars are exported.	Opened as a joint venture between Volkswagen AG and the Polmo agricultural machinery plant. Initially specialized in the assembly of SUVs and vans; in 2016, a second plant was opened in Belemžice for the production of VW Crafter. That is, it is a company with deep specialization according to the type and make of assembled cars, Head management, R&D, marketing are from Volkswagen AG (Germany).
Ursus	Specializes in the production of agricultural machinery, buses and trolleybuses under its own brand Ursus.	The company (until 2012 POL-MOT Warfama) implemented a diversification plan: it began to produce not only agricultural machinery, as originally, but acquired a bus plant, Ursus brand, motor plant; develops cooperation in R&D with the University of Military Technology and the University of Lublin. The company has attracted Turkish and Dutch investments. It built a holding company that includes subsidiaries specializing in the production of various types of products.

That is, in Poland, only Opel Polska opened as a new company, albeit long ago. The rest of the enterprises were created in the process of their purchase and re-equipment. New models, new equipment, new business processes were introduced there. Of all the national car brands in Poland, only Ursus is preserved.

Table 4 presents the main automotive companies in Romania and the history of organizational change in these companies.

Table 4 Automotive companies in Romania, the history of organizational change

Enterprise	Modern features	Implemented organizational changes
Automobile Dacia	Dacia, Romania's oldest (since 1966) and largest car company, which produces Renault Group cars, accounts for 8% of Romanian exports. Production capacity of 350 thousand cars per year. Cars are assembled under the brands Dacia (main) and Renault, 50% of car production in Romania.	It was purchased in 1999 by Renault. Renault-style models and production processes typical for Renault plants in France were introduced. A test centre was set up in 2010, part of the R&D was partially transferred, and in 2005 the world's largest logistics centre, Renault, was opened next to the plant to manage the supply of car parts.
Ford Romania	Specializes in production of Ford EcoSport, Ford Puma (previously Ford Transit, Ford B-MAX).	The company was opened on the territory of the former Oltcit car plant in Craiova (Daewoo Automobile Romania used to be located there as well). Daewoo Automobile Romania bought Ford in 2008 and rebuilt it to produce Ford cars. Currently employs 3,500 staff, production capacity of 350 thousand cars, but only 10% is used.
Roman Braşov	The company, which opened in 1921, produces ROMAN and DAC trucks for the needs of manufacturing and	The company has undergone 2 significant changes. Privatized in 2003 (94.27% of the shares were bought by the Malaysian company Pesaka Astana). The new

Enterprise	Modern features	Implemented organizational changes
	construction companies and the army. A large number of trucks are exported.	owner tried to bring the company out of losses, created an industrial park, before that there was a big reduction in staff. The second stage of change is the purchase in 2014 by Prescon Braşov. The new owner tried to restructure the company's processes, improve both business processes and upgrade equipment and products. However, in 2014 the company became insolvent, its operation was suspended in 2016, and only in 2017 it resumed (an export contract was obtained).
Igero	Manufacturer of intercity and city buses under the brand Igero. Started working in 2003.	The company was founded in 2003 as an engineering centre, without production. It first worked under the principle of production outsourcing with Roman, then moved production to the Romprim plant in Bucharest. Buses are equipped with MAN diesel engines.

We can say that the automotive industry in Romania has retained many national brands, having been able to restructure production processes in old enterprises, introducing organizational and technological innovations. For example, Dacia, despite its purchase by Renault, produces cars under its own brand despite the fact that some of the engineering is provided by the parent company. Also, ROMAN and DAC brands of trucks have remained, the bus brand Igero has appeared. Furthermore, the country also produces cars of world-famous brands. In addition, a large number of OEMs that produce components for other European plants (gearboxes, wheels), as well as tire plants (the most famous brand - Michelin) have been opened in Romania. The studies note the high importance of the production of spare parts and components for the Romanian economy [18-20].

Table 5 presents the main automotive companies in the Czech Republic and the history of organizational changes in these companies.

Table 5 Enterprises of the automotive industry in the Czech Republic, the history of organizational change

Enterprise	Modern features	Implemented organizational changes
Škoda Auto	Produces about 57% of all cars in the Czech Republic, is part of the Volkswagen Group. Founded after the First World War, it first produced trucks and only then cars. At present it produces only cars under the management of Volkswagen. It has 3 factories in the Czech Republic, and several factories abroad.	The first significant change in business was related to the purchase of the company by Volkswagen (1991). The new owner has updated the product line of cars, brought cars to the Western European and world markets, and improved the brand. At the same time, the production and logistics systems were restructured. Since 2010, a growth strategy has been adopted. This enabled the opening of Škoda production plants in China, Russia, India, and other countries. However, design and R&D issues largely remain with the parent company
Hyundai Motor Manufacturing Czech (HMMC)	Established in 2007 as an enterprise with 3,500 jobs and production capacity of up to 300,000 cars per year. Produces Hyundai cars.	It was created as a new company (all business processes transferred from the parent company), and organized cooperation between component manufacturers in the Czech Republic and Slovakia.
TPCA (joint venture Toyota, Peugeot and Citroen)	Originally a joint venture of Toyota, Peugeot and Citroen, now a manufacturer of Toyota cars (small cars) for sale in Europe.	Two stages of work: first in 2002, the company was established as a joint venture between Toyota, Peugeot and Citroën, which produced these makes for sale in Europe (mainly small cars). The company was opened as new, with business processes from Toyota. The second stage - in 2018, when the plant became fully

Enterprise	Modern features	Implemented organizational changes
		owned by Toyota and engaged only in the production of cars of this brand for Europe.
Tatra Trucks	Manufacturer of Tatra trucks for industrial, construction and military needs, also for export.	Significant organizational changes began in 2003, when the company was acquired by the American company Terex Corporation. New models were introduced, and car deliveries to the markets of the United States and Western Europe were organized. In 2011 - cooperation with DAF (purchase of DAF cabs and Paccar engines).

Apparently, the national brands Škoda and Tatra were retained in the Czech Republic, although these companies became the property of larger foreign automobile corporations. Thanks to the new owners, the companies rebuilt their processes, updated their product lines, entered new markets and were able to ensure their own growth. At the same time, new car plants of large automobile concerns have been opened in the Czech Republic, and cars of world brands are produced there. It is important to note that in the Czech Republic there are many OEM companies that supply components to both automotive companies in the Czech Republic and foreign markets.

5 Conclusions

The analysis allows us to draw the following conclusions.

1. The development of the automotive industry in the modern world has the following trends:

- Internationalization (production in different countries);
- Formation of large multi-brand concerns (production of different classes and brands of cars);
- Cooperation (OEM companies and car dealers cooperate with concerns);
- Specialization (in each country cars are made according to market needs, either for domestic consumption or for export).

2. With the accession of new countries to EU membership, as practical experience shows, the national automotive industry cannot compete with world leaders (large automakers), forcing it to either close its own car production or integrate into the global automotive system on the basis of innovative business processes (logistics, production cooperation, production technology, sales, etc.).

3. The most useful for Ukraine is the experience of Slovakia and Romania, which after joining the EU were able to maintain national brands in the automotive industry, restructure processes, upgrade car product lines and achieve significant growth in car production in the short term.

4. The experience of the EU countries, which Ukraine should borrow and implement, is that it is necessary to create conditions for attracting foreign investors to existing enterprises of automobile production, to upgrade equipment, reorganize production. This will allow establishing the production of foreign brands at Ukrainian enterprises, as well as components for them. In the legal field, such a plan can be implemented within the framework of the Association Agreement with the European Union, which provides for the possibility of duty-free export of cars to EU countries. The operation of foreign automobile concerns in Ukraine is an extremely profitable offer for both global automakers and the Ukrainian economy as a whole.

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IMPACT OF E-COMMERCE ON THE PERFORMANCE OF AGROEXPORTS IN THE CENTRAL REGION OF PERU

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Keywords: e-commerce, export performance, distribution efficiency, communication efficiency

Abstract: The objective of the research was to determine the impact of electronic commerce on the performance of agro-exports in the central region of Peru, 2020. The study was carried out from a quantitative approach with a non-experimental - cross-sectional - causally correlated research design. Using the survey technique, two questionnaires were applied to 95 agro-exporters, one for electronic commerce and the other for export performance. Using the structural equations model, it was obtained that electronic commerce in its compatibility dimension does not have a positive impact on the efficiency of the distribution of companies ($p > 0.05$) and does have a positive impact on the efficiency of communication ($p < 0.05$). Regarding ease of use, it does not have a positive impact on the efficiency of the distribution ($p > 0.05$; however, it does have a positive impact on the efficiency of communication ($p < 0.05$). Regarding the perceived utility it has a positive impact on the efficiency of distribution ($p < 0.05$), but it does not have a positive impact on the efficiency of communication. It is concluded that the compatibility and ease of use of electronic commerce positively impact the performance of communication efficiency in agro-exports and the perceived utility has a positive impact on the performance of the efficiency of distribution in agro-exports of the companies of the central region of Peru.

1 Introduction

In a globalized environment where the dissemination and use of information technologies have caused great changes in society in general and in companies, E-commerce has been one of its main tools for integration, communication and information between companies and their customers [1]. E-commerce can be explained not only as a simple type of commerce but as one of the largest marketing and strategic support systems for companies within their local and international market [2]. E-commerce changed the commercial system of companies offering great opportunities thereby achieving rapid growth and expansion of the same. For example, in Indonesia by 2019, more than 13 million companies implemented and adopted this new system, as well as 77% of internet users were looking for information on products and services in online e-commerce stores. It is necessary to take advantage of the advancement of technologies and E-commerce to help the development of companies, intensifying their use, advertising, generating and performing usual commercial functions, thereby achieving greater benefits, options and value propositions for current and potential markets that can be covered [3]. Worldwide, the sales of products and services through the internet have grown, with the countries of China, Japan and the United States being the first to use and implement their companies. In Latin America, the growth of E-commerce was between 6% and 11%, representing US $ 29,800 million in 2015 to US $ 64,400 million by the end of 2019, among the countries that registered the highest growth were Argentina, Brazil, Chile and Mexico.

In Peru, a sustained growth of 30% is maintained, but if the industry works as a team to boost online trust, and with a boost from the government, it could grow to more than 100%. Also highlighting that in Peru E-commerce is in constant growth and expansion, in addition to that according to the [4]. E-commerce in Peru has contributed 5.75% to the national GDP of 2018, highlighting the importance of carrying out this type of transactions for the country. According to the Mincetur, the companies of the agricultural sector of the Junín region had an increase in the exports of goods of 20%, whose main foods they exported were achiote, aguaymanto, chili pepper, artichoke, carob, banana, sweet potato, cocoa, coffee, caigua, among other highly valued products in the foreign market and of great income for companies in the region. Highlighting the constant growth in the use of E-commerce to carry out commercial transactions, it is gaining more and more followers among entrepreneurs considering an increase in the penetration of technological advances

The companies of the agricultural sector are immersed in the world of E-commerce at the same time that they have and use these online business platforms, they do not know the importance, help and contribution they can make to increase the sales of their products abroad and thus increase your exports. They are unaware of the great advantages of this tool, as mentioned in a study entitled e-commerce decision factors in Peruvian organizations in the retail sector [5] where it refers that although there is high potential for a greater development of electronic commerce in Peru, there is a lack of information on its potential, losing opportunities to generate a competitive advantage locally and internationally.

The main objective of this study is to determine the impact of electronic commerce on the performance of agricultural exports in the central region of Peru, serving the present so that entrepreneurs can know to what extent it supports the development and growth of companies.

2 Literary Review

2.1 E-commerce

Electronic commerce is defined as the use of the internet to carry out commercial transactions at the national and international level in an appropriate way. According to [6], electronic commerce is the process of selling or exchanging products, services and information through the internet. [7] mention that electronic commerce is mainly focused on the possibility of rapid and updated access to different research sources and the supply of goods and services, without obstacles from the spatial and temporal barriers that physical commerce has to face.

2.1.1 Compatibility of E-commerce

According to the Royal Spanish Academy, the term compatibility is defined as that, said of a person or of a thing; that it can be, function and coexist without impediment with another; From this, it can be interpreted that the compatibility factor measures how adaptable E-commerce can be with the operations and procedures of the company, that is, how much it adapts and integrates with the objectives, culture, values and way of working of the same [8]. The compatibility of E-commerce with the company depends largely on the vision, mission, objectives and strategies that govern the organization.

2.1.2 Usability of E-commerce

The perceived ease of use is the degree to which a person considers that using a specific system or technology does not require additional effort and that the use is of simple and easy way. The success of electronic commerce in companies depends on the ease of adoption and mastery of it by different areas and components that make up [9].

For [10] the widespread use of electronic commerce allows companies to take advantage of a completely new set of capabilities that create a level of global connectivity necessary for the success of the complete export. Transforming resources based on technology and specialized capabilities since they are essential for companies to achieve organizational efficiencies.

2.1.3 Perceived utility

The perceived utility as the degree to which the person considers using a system or new technology will improve results mention that electronic commerce through the internet offers an instrument that will help organizations to fulfil some of their main functions, such as promoting, coordinating and developing economic objectives of operations and strategies with their partners to strengthen, consolidate and integrate their economic activity.

2.2 Agro-export performance

According to [11], define performance as a measure of corporate goals, whether economically or strategically with respect to the export of a product or service to a foreign market, is achieved through the good implementation of export marketing strategies. Export performance can be represented in terms of recipient or customer satisfaction.

[12] mentions that there are two main categories of export performance measures: financial performance which emphasizes export sales, growth, intensity and profitability of exports; market performance which emphasizes the performance or strategic results of the export as it was possible to achieve the strategic objectives or the strengthened strategic position.

2.2.1 Distribution Efficiency

According to [13], define distribution as the process by which distributors are selected, as well as the support and commitment of distributors, are important aspects of efficiency and serve as a key export to success factors. Distribution is a key aspect of the export business; the use of resources and capabilities of e-commerce provides numerous ways in which companies can gain efficiency and improve their performance. The efficiency of distribution generated by electronic commerce allow exporters to reduce the number of channels in the distribution chain or also called the process of elimination of intermediaries.

2.2.2 Communication Efficiency

According to [10], Generally define communication efficiency as the set of activities involved in facilitating exchange. Communication efficiencies can reduce buyers' search and negotiation costs. On the other hand, he mentions that the reason why search costs decrease with e-commerce is due to the capabilities of marketing which derives a broader geographic scope from potential suppliers and buyers, with the potential of a direct conversation.

3 Research Model and Hypotheses

For the independent variable E-commerce, the following conceptual constructs and their respective items were considered:

a) Compatibility: E-commerce is in accordance with my company culture (C1) and E-commerce is in accordance with my company values (C2).

b) Usability: My company adapted to technology and it was easy for us to use electronic commerce (U1), It was easy for my company to implement electronic commerce (U2) and My company's interaction with electronic commerce was clear and understandable (U3).
c) Perceived Utility: Using electronic commerce in my company improved job performance (PU1), Using electronic commerce in my company increased production (PU2) and My company finds electronic commerce useful for the activity it performs (PU3).

For the dependent variable Export performance, the following conceptual constructs and their respective items were considered:

a) Distribution Efficiency: My company is efficient in the logistics process (electronic reservation, transport, inspections, online shipment tracking, etc.) (DE1), My company has been able to reduce the number of distribution channels (intermediaries) necessary for the export market (DE2) and My company brings products to the international market quickly (DE3)
b) Communication Efficiency: My company is efficient in the exchange of information between clients and partners (CE1), In general my company realizes the efficiencies in after-sales service (CE2) and My company is efficient in researching export markets (CE).

From which the following conceptual model and hypothesis are established (Figure 1).

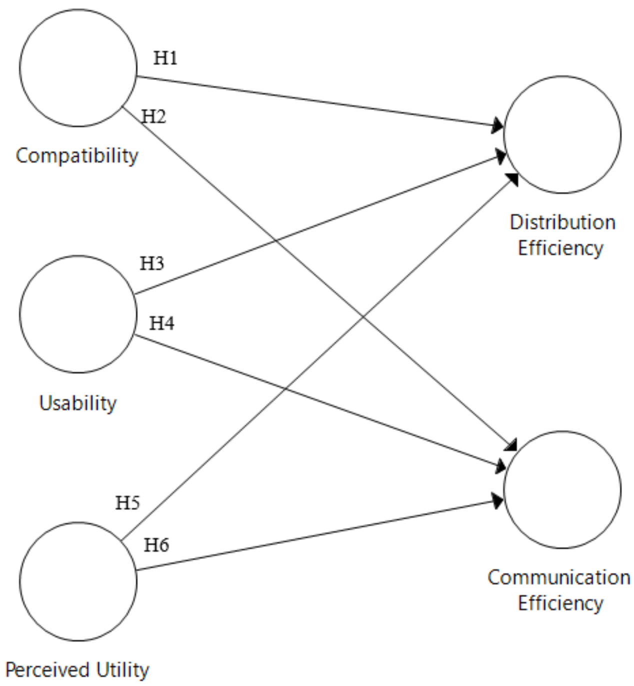

Figure 1 Conceptual model and hypotheses

H1: The Compatibility of e-commerce generates a positive impact on the Distribution Efficiency of agro-exports.

H2: The Compatibility of e-commerce generates a positive impact on the Communication Efficiency of agro-exports.

H3: The Usability of e-commerce generates a positive impact on the Distribution Efficiency of agro-exports.

H4: The Usability of e-commerce generates a positive impact on the Communication Efficiency of agro-exports.

H5: The Perceived Utility of e-commerce generates a positive impact on the Distribution Efficiency of agro-exports.

H6: The Perceived Utility of e-commerce generates a positive impact on the Communication Efficiency of agro-exports.

4 Method

A correlational cross-sectional deductive study was conducted between January 2020 and September 2020.

4.1 Population and sample

The study population was made up of 126 managers or owners of agro-export companies, between men and women within a range of 18 to 65 years of age, who carry out their business activities from the Junín region; distributed in 9 provinces: Huancayo, Concepción, Jauja, Satipo, Tarma, Chanchamayo, Yauli, Junín, Chupaca. The representative sample consisted of 95 agro-exporters, obtained through the finite sample formula with a margin of error allowed of 5%, with a “p” factor of 0.5 and “q” of 0.5, confidence level of 95%.

4.2 Data collection instrument

A directed questionnaire was developed based on 8 questions for the electronic commerce variable (2 for compatibility, 3 for ease of use and 3 for perceived utility) and 6 questions for the export performance variable (3 for distribution efficiency and 3 for communication efficiency). For the validation of the instrument, the Delphi methodology was followed, by which the background validation was carried out with 3 experts in Administration and International Business, the form was validated through the application of the survey to 45 agro-export entrepreneurs, who participated in simultaneously with the pilot. After the first correction of the observations made by the experts, the instrument underwent a second validation, in charge of 2 experts in Administration and International Business and 2 businessmen from the sector. In these stages (for the validation of substance and form), the evaluation of the questions was considered on a four-point scale (one was totally in disagreement and four was totally in agreement), these stages verified the understanding of the questions, identified gaps in the reagents, they eliminated questions and refined the data collection mechanism.

5 Results

5.1 *Assessment of the Measurement Model*

Table 1 shows the measurement analysis of the model, based on the reliability and validity of the measurement scales. With regard to reliability, the internal consistency of the scales is evidenced by the Cronbach Alpha value (between 0.630 and 0.969) and the composite reliability (between 0.810 and 0.980). With respect to convergent validity, all factor loadings are above 0.815. Likewise, all the scales have percentages of average variance extracted (AVE) greater than 50%. The discriminant validity of the construct was tested by the Fornell Larcker criteria, which verifies the independence of each of the scales, considering that the square root of the AVE is greater than the correlations with the rest of the scales. In all cases, the assumption was met.

Table 1 Results of the model measurement analysis

Variables	Cronbach alpha	Composite reliability	Factor loads (range)	Average variance extracted (AVE)	Discriminant Validity
Compatibility	0.630	0.810	0.823 – 0.826	0.680	0.825
Usability	0.721	0.851	0.580 – 0.916	0.665	0.815
Perceived Utility	0.762	0.870	0.627 – 0.927	0.696	0.834
Distribution Efficiency	0.775	0.876	0.628 – 0.942	0.709	0.842
Communication Efficiency	0.969	0.980	0.961 – 0.980	0.941	0.970

As shown in Figure 2, in all cases an R2 greater than 0.112 was obtained, which is very significant, showing that the model significantly explains the variance of the conceptual constructs of the dependent variable.

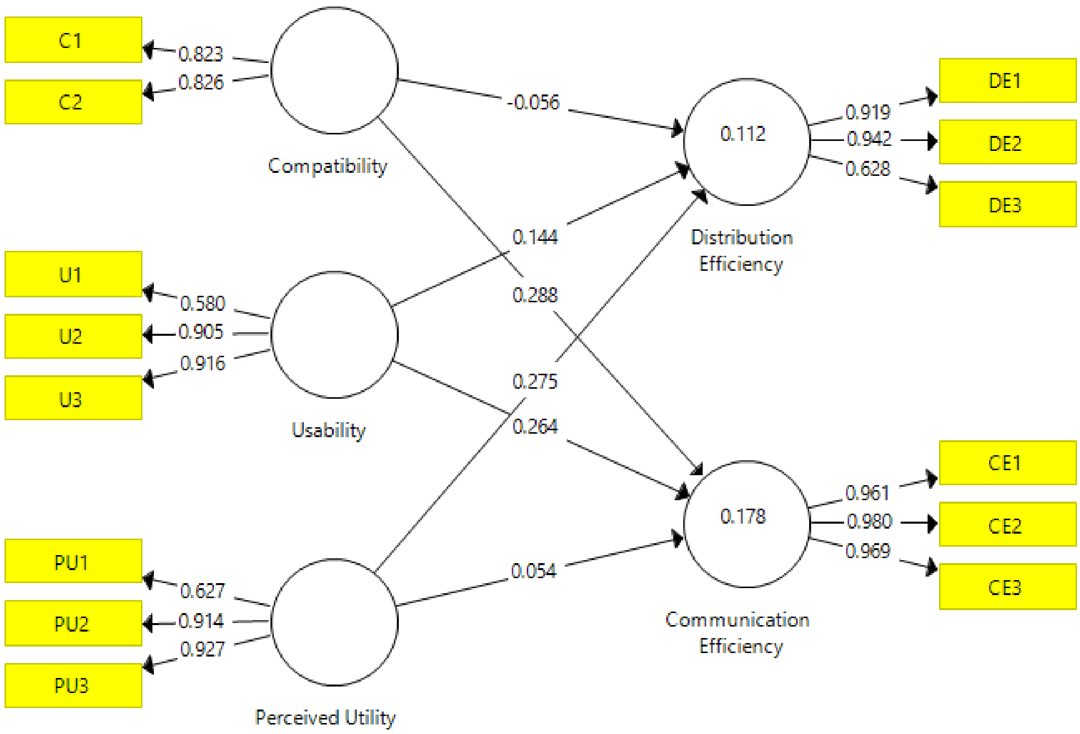

Figure 2 Results for the hypothesized model with structural equations

5.2 *Assessment of the Structural Model*

After verifying the validity and reliability of the measurement model, the relationships of the constructs were tested [14]. The hypotheses were tested by examining the road coefficients and their significance levels. Bootstrapping was performed with 5000 subsamples to verify the statistical significance of each of the road coefficients. Figure 3 shows the estimated trajectory of the PLS analysis.

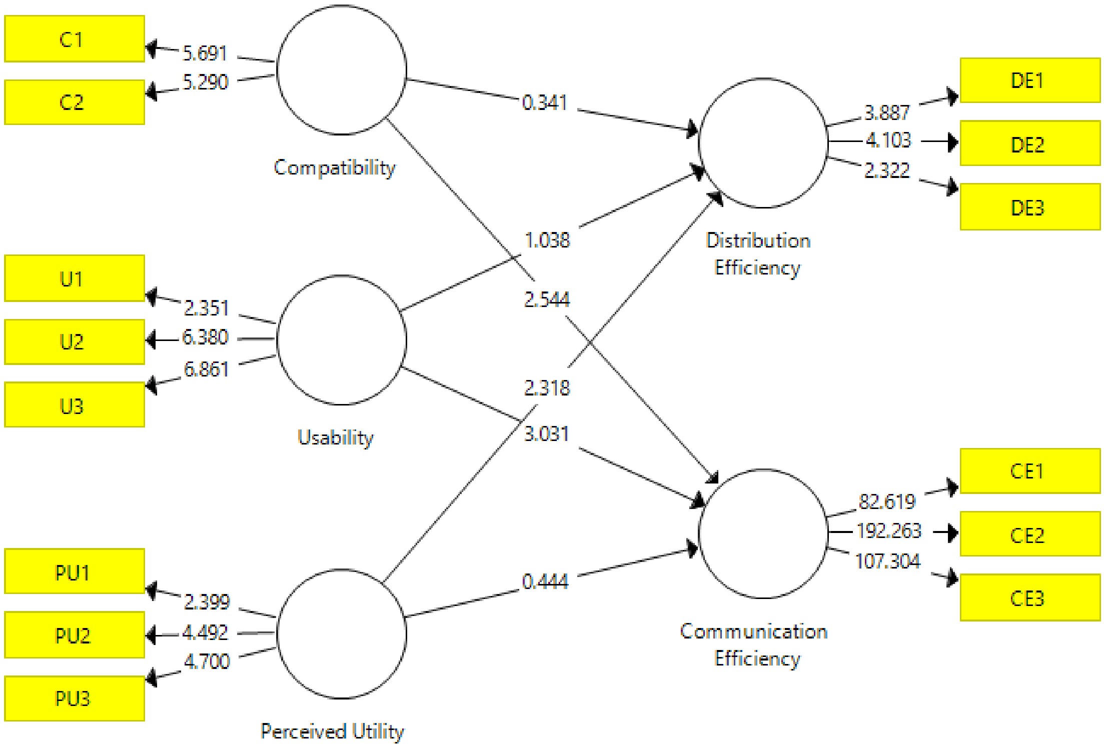

Figure 3 Modeling digital transformation and individual job performance

Of the 6 proposed hypotheses, H2, H4 and H5 are accepted as shown in Table 2.

Table 2 Results of the model structure analysis

Hypotheses	Mean sample	Standard deviation	Beta	p value	Decision
Compatibility -> Distribution Efficiency	-0.056	0.164	0.341	0.733	Denies H1
Compatibility -> Communication Efficiency	0.291	0.113	2.544	0.011	Accept H2
Usability -> Distribution Efficiency	0.131	0.139	1.038	0.299	Denies H3
Usability -> Communication Efficiency	0.276	0.087	3.031	0.002	Accept H4
Perceived Utility -> Distribution Efficiency	0.277	0.119	2.318	0.020	Accept H5
Perceived Utility -> Communication Efficiency	0.057	0.122	0.444	0.657	Denies H6

6 Discussion and conclusion

6.1 Regarding the impact of e-commerce compatibility on the communication efficiency of agro-exports

The compatibility of electronic commerce has a positive and significant impact on the efficiency of the communication of agro-exports ($p < 0.05$), this is in line with that referred to by [1] who recommend that to continue achieving better communication with customers they should pay close attention to their online sales, improving and implementing a series of fundamental guidelines around information, communication and additional functions that allow fluid and continuous communication with them ; They also highlight that an efficient immersion in the world of electronic commerce will lead to better results for companies. Likewise, it agrees with what was indicated by [6] who highlight that there are three fundamental factors for the success of a company on the internet and electronic commerce and they are: the organization, the technology and the environment, with the organization being the most important factor, mentioning that if it is committed, involved and operates efficiently, it will have positive results in relations and communications with its current and potential clients, in addition to obtaining the results expected by them. For its part, [5] mentions that the organizational culture and the flexibility to adapt to electronic commerce promote attitudes associated with the innovation of decision makers and that it has a significant impact on the interaction with customers, search for potentials, reduction of intermediaries, a closer and more direct relationship and collaboration with the target audience, thus achieving the goals and objectives of the companies. In conclusion, for companies to exploit all the potential that electronic commerce can offer them, the entire organization must be involved, implementing, improving and promoting the interior and exterior of it, thereby achieving a more effective relationship, communication and information exchange. clear and understandable with current and potential customers of companies.

6.2 Regarding the impact of e-commerce usability on the communication efficiency of agro-exports

The ease of use of electronic commerce has a positive and significant impact on the efficiency of agro-export communication ($p < 0.05$), this is in line with what is reported by [10], who recommend that for to achieve efficient communication, we should continue to adapt to electronic commerce technologies, since it would increase access to customer information and transparency of information, generating a reduction not only in search costs but also in monitoring and execution costs. The efficiency of communication through electronic commerce also generates a reduction of information asymmetries between buyers and sellers by providing complete information, which would lead to better results for the company. In conclusion, in order for companies to develop optimal communication efficiency, they should develop specialized capabilities in communication and e-commerce promotions, as this would be a clearer and more understandable way to manage buyers' expectations in export markets. Likewise, the development of the adaptation of electronic commerce technology has resulted in efficiencies in logistics on a global scale, and in turn a more effective after-sales service.

6.3 Regarding the impact of e-commerce perceived usefulness on the distribution efficiency of agro-exports

The perceived utility of electronic commerce has a positive and significant impact on the efficiency of agro-export distribution ($p < 0.05$), in particular we found that, to achieve distribution efficiency, it was necessary to adopt a manoeuvre to optimize resources and capacities of electronic commerce, managing to perform the specific tasks of the company more quickly. This is in line with what is referred to by [15], who recommends that for companies to continue obtaining a better distribution, they should take advantage of new technologies and at the same time be able to adapt and create capacities to align with the market and achieve better results. Likewise, [13] suggest that the closer the relationship with the distribution, the success of the commercialization materializes and the relationship must be managed with objectives to be achieved in the long term.

Highlight that for distribution efficiency [10] it is necessary to capture a competitive advantage, suggesting that the competitive advantage can be obtained in various ways: an efficiency advantage, an effectiveness advantage or an efficient advantage of effectiveness and is in turn significantly impacting with customers by which it could operate in a more efficient way and obtain positive results. Efficiency in the delivery time of exported products constitutes a key criterion for selecting foreign suppliers and ensuring success in the market in which they operate. In conclusion, the efficiency of distribution is key to export, also the use of its resources and electronic commerce capabilities provides us with numerous ways to achieve that companies can gain efficiency in logistics processes and improve the performance of exports in the companies.

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