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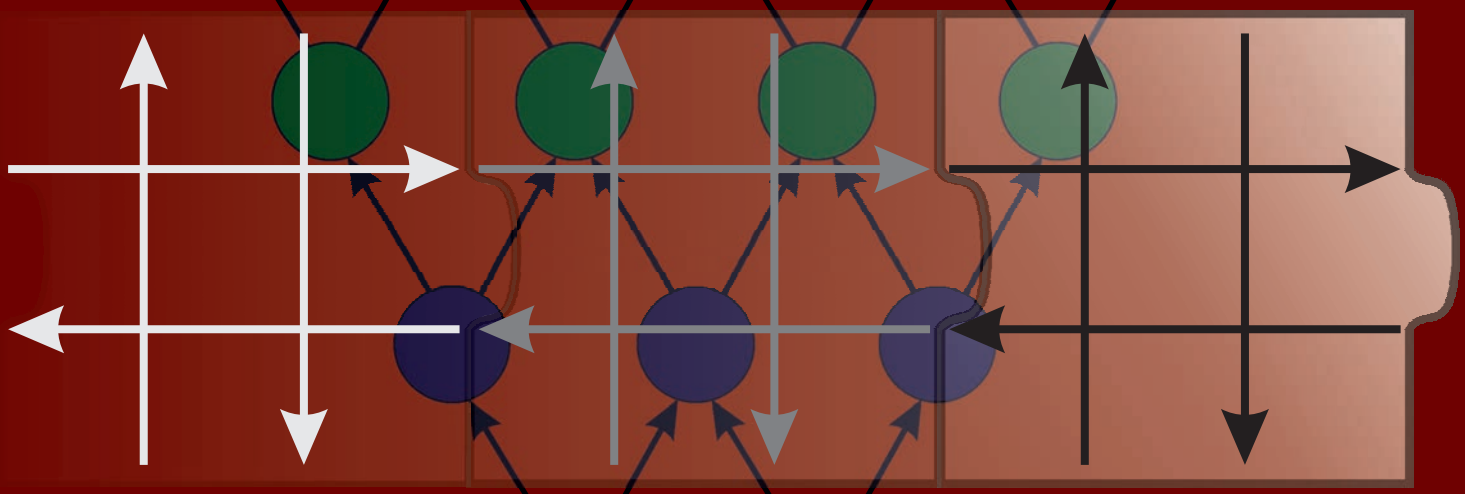

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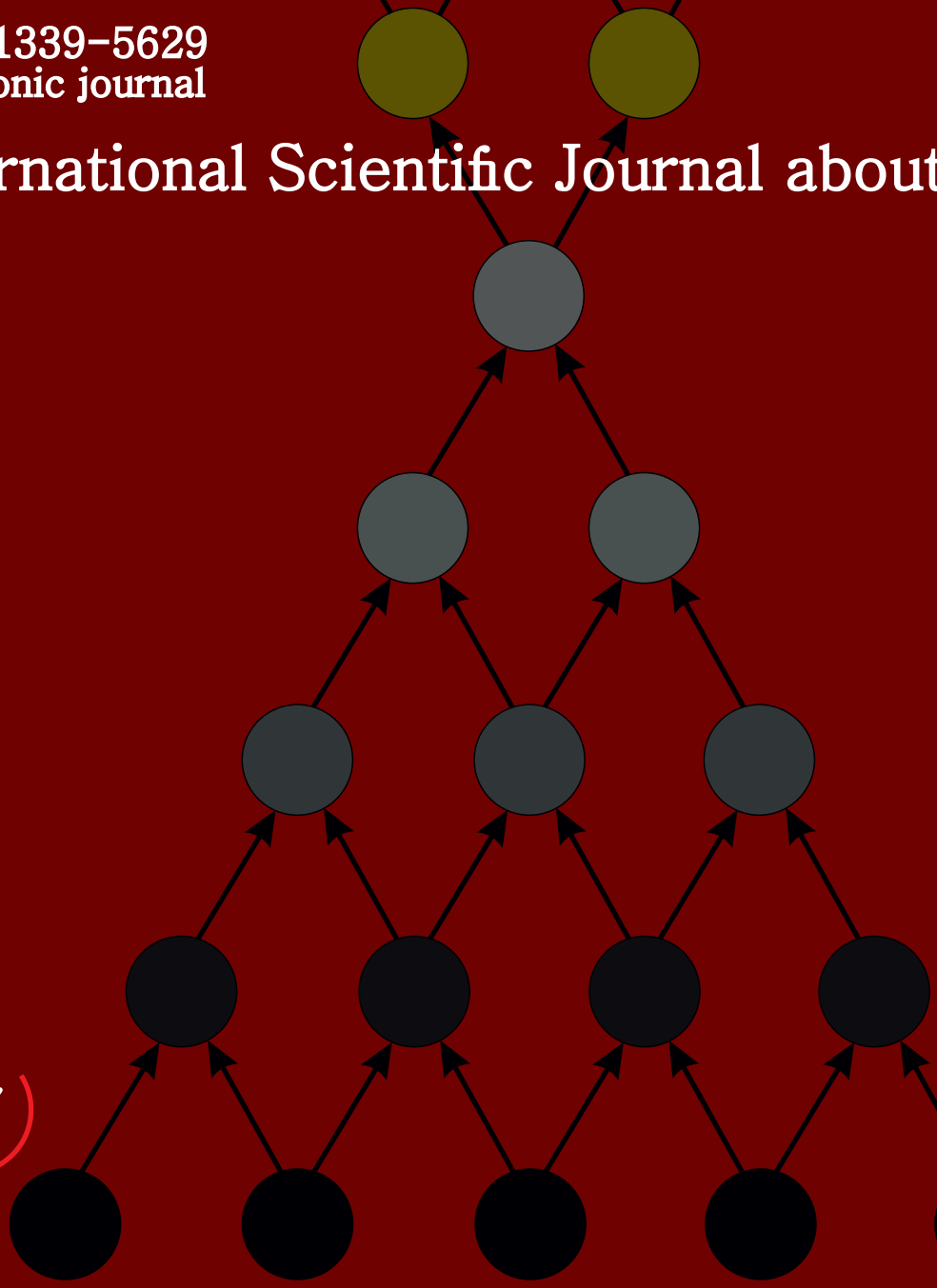

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Environmental sustainability and operational performance in the road freight sector

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Keywords: operational performance, canonical correlation analysis, environmentally sustainable practices, trucking industry and road freight, logistics management.
Abstract: Road freight plays a pivotal role in the movement of goods from the point of production to the point of consumption. Transportation of freight by road is associated with high operational costs which increases cost of landed goods. The use of trucks is associated with greenhouse gas (GHG) emissions and congestion especially in urban areas. The trucking industry dominates freight movement in many countries including South Africa, necessitating the need to improve its operational performance. While researchers argue that implementation of environmentally sustainable practices (ESP) by trucking firms is likely to influence operational performance (OP), the actual effect is unknown. The purpose of this study was to investigate the effect of ESPs on OP among trucking firms. A survey of 124 trucking firms was conducted and the data was analysed using canonical correlation analysis. The ESPs identified were energy efficiency, driver behaviour, and advanced technology. The results revealed that there is an inverse relationship between ESPs and OP, with advanced technology being a major contributing practice to the relationship. Limited funding was identified as a major inhibitor to the implementation of ESPs among the trucking enterprises. This study informs managers of trucking enterprises that the implementation of environmentally sustainable practices would not likely result in higher operational performance, as such, they should implement the practices as a social good as opposed to for profits. The study investigated a complex phenomenon in an important sector of the economy in South Africa and provide some policy directions.

1 Introduction

The likely adverse effect of greenhouse gas emissions (GHG) calls for far-reaching changes in the approaches towards sustainable transportation systems [1]. The negative environmental effects of road freight transportation are huge in terms costs to the firms and society, thus require innovative tactics on the utilisation of transportation systems in a more sustainable manner [2]. Environmental concerns are fast becoming a top managerial concern due to customers' desire to trade with environmentally conscious enterprises. Numerous international studies have probed the intricacies of road freight sustainability research from developed economies like the United States and European countries exploring diverse strategies such as alternative fuels, smart logistics, and vehicle electrification to mitigate environmental impact [3]. Studies by [4-7], collectively highlight the challenges faced by the road freight sector in South Africa in achieving environmental sustainability while maintaining operational efficiency. [4] Identifies operational challenges such as poor road infrastructure, traffic congestion, and poor maintenance strategies that hinder optimal delivery of goods. [5] Emphasizes the importance of addressing socio-economic factors within the transport sector to promote sustainability. [6] Discusses the negative environmental impacts of the freight system, including air pollution and energy consumption. [7] Explores strategies for sustainable freight transportation, considering the balance between economic welfare and environmental impact. These papers provide insights into the challenges and provide potential strategies for achieving sustainability in the South African road transport sector.

While most companies strive for flexibility, reliability, and cost reduction in the transportation of goods, there has been a growing trend to implement environmental sustainability initiatives to achieve the stated efficiency and effectiveness objectives. Implementation of sustainable practices in transportation requires top management support [8]. Transport operations activities contribute greatly to GHG emissions problems yet research on the potential of environmental sustainability to promote efficiency and competitiveness among trucking firms remains inadequate [9]. When analysing systems to do with freight transport activities, three main topics emerge, namely business operations, operational performance, and

environmental influence [10]. Operational performance (OP) refers to the efficiency and effectiveness of an organisation's efforts to achieve its set objectives [11]. Within trucking companies, the objectives might include fuel efficiency, reduced logistics costs and minimal environmental impact (noise, pollution, and accidents) [11] . Thus, trucking firms might focus on monitoring their energy efficiency, maintenance costs and reliability metrics to remain competitive. Carbon emissions from trucks are quite harmful to the environment; as such, some countries impose payment of carbon taxes which subsequently erode profitability [12]. Therefore, firms should implement sustainable practices that lessen the cost of logistics as well as cost of goods to improve their operational performance.

In South Africa, freight movement is predominantly by road, which makes trucking services critical to the manufacturing and distributive industries. The trucking sector is even more important in the port cities, which link the inter-land and the international shipping lines [13]. This implies that the port cities are likely to bear the cost of GHG emissions from the large number of trucks that drop and pick freight from the ports. Despite the likely known benefits of adopting sustainable road freight transport, there is little that is known regarding the relationship between environmentally sustainable practices and operational performance of trucking firms. Prior research on sustainable freight transport and operational efficiency focused on the movement of goods through the sea in Finland and established the practices can lead to developing a competitive advantage [13]. A study from Belgium [14] investigated the implementation of sustainable practices to minimise GHG emissions and operational costs by using an optimal truck chassis size. Prior research has also established that technology and innovation play a pivotal role in improving timeous cargo delivery in the road freight industry [15]. The limited research on the effect of environmental sustainability and operational performance of trucking firms calls on researchers to fill the knowledge gap. The polemic objectives of greening the transport industry as well as minimise the cost of transport make spell the significance of this study to shippers, operators, practitioners and relevant public agencies. The study addressed the following research questions:

1. What is the extent of the implementation of environmentally sustainable practices (ESPs) among trucking firms?
2. What is the relationship between ESPs and OP of trucking firms?
3. What challenges do trucking companies face when implementing ESPs?

The rest of this paper is divided into literature review, material and methods, results, discussion, conclusion, and recommendations.

2 Literature review

2.1 Road freight sector in South Africa

South Africa has the largest and most developed transport and logistics infrastructure in the Sub-Saharan Africa. South Africa is identified as a key emerging economy owing to its membership in the BRICS. The freight and logistics market in South Africa is worth about USD 21.53 billion in 2023 and is expected to grow to about USD 30 billion by 2030 [16]. The road freight sector is one of the largest as it accounts for about 75 percent of commercial cargo in South Africa. The road freight sector comprises of a few large players such as Imperial Logistics and many medium and small enterprises. The micro players are also well represented where there are owner drivers. The sector has low entry and exit barriers, thus, there are many competitors offering varying quality of service. The lack of strict regulation implies that operators are profit focused and initiatives related to sustainable transport might not be a priority as they require extra capital investments. Most South African industries rely heavily on trucks, which have become the dominant mode of transporting about 80 percent of commercial freight in South African. As such, road transport is the heartbeat of the South African economy [17]. Like any other industry in South Africa, the road freight industry has been affected by several challenges, such as electricity outages, fuel price hikes and continuous industrial unrests. The instability in electricity supply is characterised by many hours of load shedding a day, thus increasing warehousing and transport costs as retailers order more frequently [18]. In addition, fuel prices are going up not only in South Africa but worldwide and this has impacted the cost of road freight services and the logistics industry at large. Consequently, the logistics increase resulting in an increase of the price of goods [18]. The increasing trucking costs can also be associated with labour issues resulting in protests that increase security costs. The protests result in congestions, and higher emissions from the trucking industry in South Africa. In addition, deliveries are delayed resulting in temporary shortages of goods and services and in some cases damages, especially where perishable goods are involved [7]. The reliability, dependability, efficiency, and effectiveness of logistics activities have thus been jeopardised by such challenges. While one of the areas that affect operational performance is Driver Behaviour (DB), their constant dis-satisfaction over their conditions of service has worsened their behaviour [19].

2.2 Operational performance of trucking enterprises

Operational Performance (OP) refers to the ability of an organisation to streamline its processes to maximise its outputs by minimising costs, improving speed of service, flexibility, and quality of service [10]. Further it is contended that trucking firms strive for consistent delivery of freight to as contracted by shippers. Given that business environments are constantly changing, the trucking

industry still needs to remain competitive by improving its OP [9]. Whereas there are different ways to measure operational performance, the common metrics have been to make use of both financial and non-financial methods [20]. In this study, energy efficiency, maintenance costs and reliability were used as measure of OP. Prior studies have argued that operational performance can be improved by diligently managing the related activities to ensure optimal results by reducing costs and improving service levels, which might involve acquiring some capabilities from experts, [21]. While research on operational performance is mature, little is known about whether environmental sustainability practices can improve operational performance of trucking firms.

2.3 Environmental sustainability

The three pillars of sustainable freight transportation are economic, social, and environmental [22]. This present study, however, focused on environmentally sustainable practices (ESPs) within trucking companies. Environmental challenges happen on land, water, and in the air and are mainly caused by business operations, human activities, and/or natural disasters The environmental sustainability is described as the ability to utilise the environment without hindering the present and future inhabitants [15]. Transport, which is part of logistics is a key contributor to sustainable development because of its impact on the environment in terms of accidents, pollution (land, water, and air), energy consumption, and the noise it generates [14]. The sustainable freight logistics systems require transportation that is safe, fuel-efficient, and environmentally friendly as the costs associated with this heavily erode profitability and reduce the overall OP of firms [23]. is solely concerned with conveniently planning the movement of goods using the minimum cost in a sustainable way [22]. Thus, trucking firms are expected to implement some environmentally sustainable practices to reduce the negative impacts of transportation to the environment. This is because road freight movement activities harm the atmosphere and the environment through the emission of gases and consumption of non-renewable energy [22]. Prior research has also argued that implementation of transport sustainable practices such as fuel-efficient engines, advanced technologies, improved driver behaviour require significant initial capital investments which is sometimes not readily available. Furthermore, it not known whether firms that implement the sustainable practices can improve their operational efficiencies and effectiveness.

2.3.1 Fuel efficiency

Fuel constitutes a large share of the cargo movement operating costs incurred in the road freight industry, which are mostly related to GHG emissions from an environmental perspective [14]. In the UK, freight transport had a 38% share of the total fuel consumed in 2017 [24]. Fuel consumption per km is a very important indicator of the efficiency of the vehicles used in a trucking industry as well as impact on the environment [9]. Making vehicles more fuel efficient can be necessitated by proactive or cost-driven fleet acquisitions [1]. The road freight industry needs to employ technical elements of logistics within their businesses to ensure that sustainability goals and aims are attained [25]. They further argue that the development of road transportation policies on fuel efficiency measurements will help attain GHG emission reduction goals within the road freight industry. The key to carbon-free freight transportation lies in fuel-efficient initiatives on road transportation systems to achieve a green circular economy and, in that regard, various activities can be undertaken to ensure fuel-efficient transport operations. The activities include proper scheduling, less idling time, speed reduction, and congestion avoidance as some practices that can help to improve fuel efficiency [7]. The achievement of fuel efficiency within the trucking industry goes further to include various operational measures, such as vehicle utilisation optimisation, empty leg minimisation, right vehicle size and type choice for each operation, and promoting efficient driving [26].

2.3.2 Advanced technology (AT)

Application of advanced technologies helps to achieve high efficiencies in truck fleet management by facilitating the use of automated routing and scheduling systems, automated documentation and billing systems, vehicle and freight track and trace capabilities, and maintenance planning systems among others. Some technologies can monitor driver behaviour and road surface conditions to prevent accidents and avoid mobility disruptions. Some of the advanced technologies can monitor GHG emissions and the likely air, noise and water pollution and to help management take corrective actions in good time through maintenance or decommissioning some of old vehicles. Environmental sustainability was not a popular concern until the 1980s but interest in the inclusion of transportation technology had started long before that [7]. Many road freight transport companies are making use of advanced technology (AT) in all areas of operation in the industry due to the benefits that it brings. The complexity of transportation activities renders the use of advanced technology a necessity [27] while it is found that the use of advanced technology had significantly improved tracking of cargo in transit [13]. Technology plays a pivotal role in enhancing environmental quality and company performance. A study on the Japanese transport industry found that technology innovation improved performance and that the incorporation of high efficiency and low carbon reporting technologies was important to achieve environmental sustainability [23].

2.3.3 Driver behaviour (DB)

Freight transportation is highly dependent on drivers who provide timeliness and safety along the route[19],

besides infrastructural and technical developments, there is a need for policy and driver behaviour changes if the trucking industry is to continue to thrive [2]. The performance of truck drivers has a huge bearing on how customers perceive the service offered by trucking companies[28]. A fossil fuel-based transportation system is heavily dependent on human (especially drivers) interactions with the environment [28]. Aggressive driving wastes energy, while improved driver behaviour (DB) reduces the amount of fuel consumed. Thus, it is important to have precise knowledge of human aspects that impact OP as this will help in the manufacturing of vehicles that are easy to use and provide much-needed constant feedback for decision making [29]. DB is concerned with dynamic driving characteristics, such as road safety, fuel efficiency, and good driving patterns [26]. The six (6) components of the total cost of ownership (TCO), three (3), namely fuel, insurance, and service, maintenance, and repair (SMR), are heavily influenced by DB [30]. Improved DB, where drivers drive smoothly and make informed cautious driving decisions, keep insurance premiums constant, or reduce them, reduce fuel consumption and overall truck maintenance costs. However, the debate whether driver behaviour as sustainable transport practice can affect operational performance of a trucking firm remains inconclusive.

3 Methodology

The study followed a positivism paradigm. Positivism targets accuracy, generalisability, consistency, and replicability [31]. The quantitative approach allowed for the testing of the relationship between ESP and OP objectively. The main objective was to investigate the relationship between operational performance and environmentally sustainable practices. A survey was conducted, and data was collected using a structured questionnaire. The scale questions made use of the five-point Likert-type scale where 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree and 5 = strongly agree. The sample for this study consisted of trucking companies in the Western Cape, South Africa. A total of 124 valid responses was received from respondents who comprised of owner, logistics managers, operations managers, supervisors, or their equivalents involved in day to day running of the trucking enterprises.

Descriptive statistics were used to determine the extent to which trucking enterprises have implemented ESPs. Exploratory factor analysis was used as a concept validity technique. Reliability analysis assessed the internal consistency of the scales. Canonical correlation analysis (CCA) examined the relationships between the measures of ESPs (driver behaviour, advanced technology, and fuel efficiency) and measures of OP (energy efficiency, cost per km, maintenance costs and reliability). The data analysis model is depicted in the Figure 1.

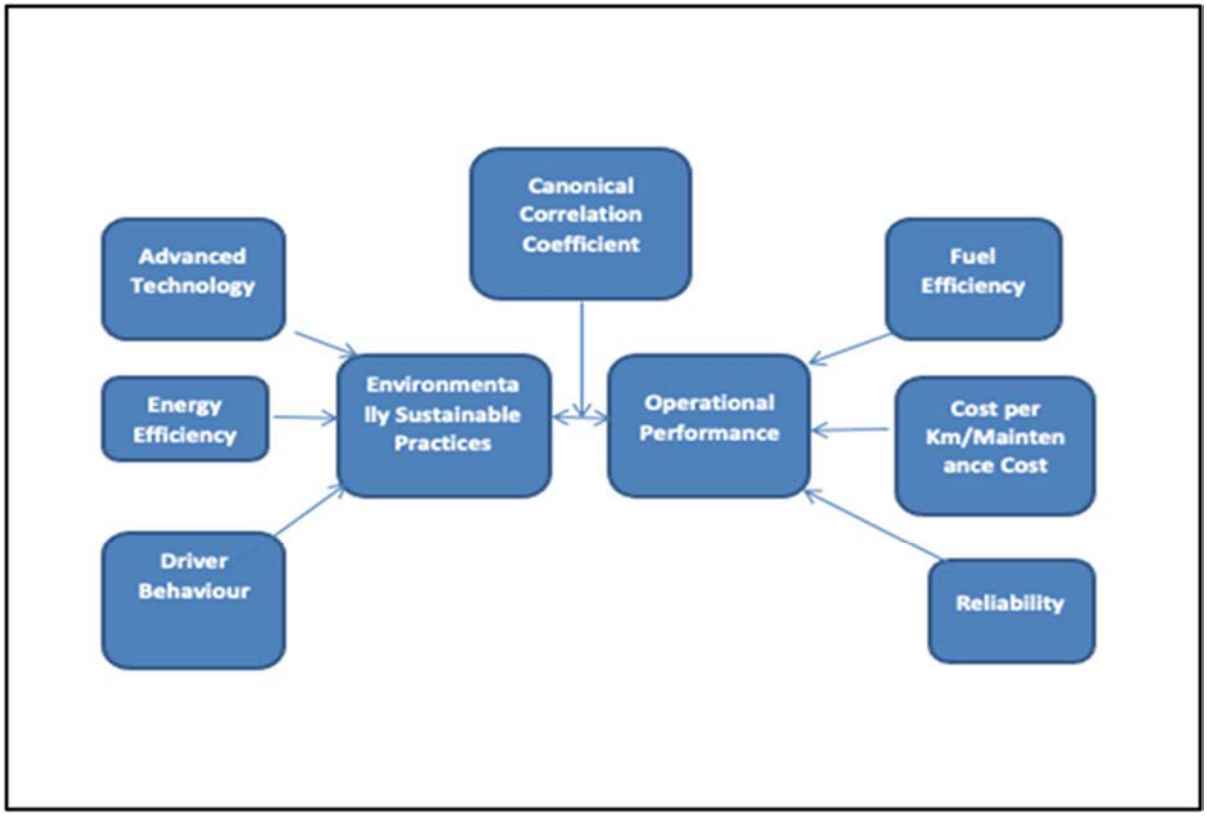

Figure 1 Data analysis model

Appropriate ethical considerations were considered during the formulation of the study and in the data collection procedures to ensure privacy and confidentiality of the respondents.

4 Results

4.1 Respondent demographics

The results show most of the respondents were males (see Table 1). In addition, 86.3 percent of the respondents had at least a diploma from a tertiary institution; implying some professional training in transport, logistics or management, thus, had the expected knowledge to understand the requirements of the research. In terms of job positions, most of the respondents were either managers, operations managers, or owner managers.

The study sought to find out whether companies were implementing some form of environmentally sustainable practices (ESPs). A dichotomous question was presented to the respondents where they were to answer yes/no. Surprisingly, most of the firms (80.6 per cent) were implementing ESPs, implying that many of the firms in the road freight industry were familiar of the concept of green transportation. One of the sustainable transport initiatives involves training drivers to improve their driving behaviour. The study sought to know whether the firms were offering any form of driver training. The results obtained (Table 2) indicated that most of the trucking firms (79.9 per cent) offered driver refresher courses at least once every two years. The results might imply that firms that offered driver refresher trainings were acknowledging that the behaviour of their drivers had a significant bearing on their operating costs as well as their overall OP, as argued by [3]. The majority of the firms were either small or medium confirming the national demographic of the road freight industry whereby there are few large enterprises with a majority of the firms being small and medium in size (Mordor Intelligence, 2023).

Table 1 Respondent demographics

Demographics	Percentage (%)
Gender	
Male	75.0
Female	18.5
Prefer not to say	6.5
Level of education	
High School certificate	8.1
National certificate	5.6
Diploma	15.3
Undergraduate degree	30.6
Honours degree	21.8
Masters/PhD	18.6
Job Position	
Owners	23.4
Operations Managers	23.4
Managers	23.4
Supervisors	12.1
Other	8.0

Table 2 Driver refresher courses

	Refresher course	Not at all	After two years	Yearly	Twice a year	Total
Firm size	Micro	13.7%	0.0%	0.8%	1.6%	**16.1%**
	Small	4.0%	4.8%	24.2%	12.1%	**45.1%**
	Medium	1.6%	2.4%	9.0%	21.8%	**34.8%**
	Large	0.8%	0.0%	0.0%	3.2%	**4.0%**
	Total	**20.1%**	**7.2%**	**34.0%**	**38.7%**	**100.0%**

4.2 Extent of ESP Implementation

The extent of ESPs implementation among the trucking firms was investigated and results were presented on Table 3. The extent was measured as either being low, moderate, or high. On average over 80.6 percent of the firms do implement the ESPs related to driver behaviour, advanced technologies and energy efficiencies. Therefore, the implementation of ESPs by trucking firms is to a high extent. This implies that many of the trucking firms are aware of the negative effect of GHG emissions from freight transport vehicles and are ready to implement some initiatives to minimise the effects.

Table 3 Level of ESP implementation

Code	Indicators	Low extent	Moderate extent	High extent
Driver behaviour		**7.9%**	**11.4%**	**80.6%**
DB1	Bonus systems encourage good driver behaviour	38.7%	16.1%	45.2%
DB2	Internal driver training programmes help ensure hiring of good quality drivers	8.1%	34.7%	57.2%
DB3	The life span of trucks heavily depends on driver behaviour	0.0%	3.2%	96.8%
DB4	Driver training works – and it can save the business money	0.0%	11.30%	88.70%
DB5	Driving style affects other vehicle running costs (e.g., insurance)	0.8%	1.6%	97.6%

DB6	Driving performance has a huge bearing on how the customers perceive the trucking companies	0.0%	1.6%	98.4%
Advanced technology		**2.8%**	**14.0%**	**83.2%**
AT1	Automatic transmission trucks can reduce the carbon content of the fuel used	1.6%	16.1%	82.3%
AT2	Gas emission control technologies are an essential tool for managing vehicle emissions	0.0%	6.5%	93.5%
AT3	Driver monitoring software proactively tackles the source of potential accidents and ensures that drivers are not being put under pressure to take risks on the road to meet targets	4.8%	25.0%	70.2%
AT4	GPS allows timely sharing of information that can help improve environmental sustainability	7.3%	15.3%	77.4%
AT5	Telematics helps companies to quickly identify areas that need action to reduce a negative impact on the environment	1.6%	11.3%	87.1%
AT6	Vehicle tracking helps monitor where vehicles are in real time and provides information on traffic and best routes to use	0.0%	1.6%	98.4%
AT7	Remote vehicle diagnostics technologies help reduce the overall maintenance cost of trucks	0.8%	15.3%	83.9%
AT8	Remote vehicle diagnostics can help avoid downtime and possible fuel leaks	6.5%	21.0%	72.6%
Energy efficiency		**0.7%**	**8.9%**	**90.5%**
EE1	The amount of gas emitted, and the total energy consumed by trucks can be reduced by in-vehicle eco driving systems	0.0%	4.8%	95.2%
EE2	Optimal truck routing and scheduling has been seen as one of the means to help companies reduce their energy consumption	0.8%	2.4%	96.8%
EE3	Proactive and cost driven truck acquisition necessitates energy efficiency	0.8%	21.8%	77.4%
EE4	Energy consumption can be increased by driver behaviour	0.0%	0.8%	99.2%
EE5	Uncoordinated routing translates into further distances travelled and more energy consumption	0.0%	0.0%	100.0%
EE6	Following speed limits and cruising speeds aid fuel efficiency	2.4%	23.4%	74.2%

Exploratory factor analysis (EFA) was used to extract the latent components from the indicators related to ESPs and OP. Prior to conducting the exploratory factor analysis, two diagnostic tests were carried out to check the factorability of the data. These tests were Kai-ser-Meyer-Olkin of Sampling Adequacy (KMO) and Bartlett's test of sphericity. Bartlett's test of sphericity should have a p-value less than 0.05 ($p<0.05$) for the analysis to be considered significant, while the KMO index ranges from 0 to 1, with 0.6 being suggested as the minimum value for a good factor analysis [28,32]. Both the ESPs and OP had a KMO value of 0.687 and 0.867, respectively, which were above the minimum threshold of 0.6, signifying their suitability for factor analysis. Bartlett's test of sphericity was statistically significant ($p<0.05$) as expected.

A set of three components related to ESPs and OP were extracted using PCA based on eigenvalues greater than 1. The extracted components were rotated to obtain the factor patterns using the varimax rotation. The result is provided in Table 4. The extracted components were interpreted as advanced technology with three indicators (AT8, AT7, and AT6), energy efficiency with three indicators (EE2, EE4, and EE1) and driver behaviour with two indicators (DB3 and DB4) for the ESPs. The second set of three components was related to operations performance construct and were interpreted as operations maintenance had nine indicators, operations reliability with four (4) indicators and operations efficiency with two indicators. All the indicators that were selected for each component had a factor loading of 0.5 and above, which shows that they had sufficient variance explained for the given construct [32,33]. Reliability analysis was done to check if a given factor was consistently reflecting the construct it was measuring. Cronbach's alpha coefficient is the commonly used test, and it has a threshold of 0.6 [30,34]. Reliability analysis was tested and presented under Table 5. The results clearly show the highest value of 0.914 for operational maintenance and the lowest of 0.582 for driver behaviour. For ESP, advanced technology was within the acceptable threshold value, while driver behaviour and energy efficiency were below the threshold, however, they were retained for theoretical reasons. In terms of OP, both operational costs and reliability had high internal consistency reliability with Cronbach's alpha values above 0.8, which was acceptable.

Table 4 Rotated component matrix

Indicator code	Indicator description	Factor loadings	Reliability	Latent variable
	Environmental sustainability			
AT8	Remote vehicle diagnostics can help avoid downtime and possible fuel leaks	0.808	0.755	Advanced technology
AT7	Remote vehicle diagnostics technologies help reduce the overall maintenance cost of trucks	0.778		
AT6	Vehicle tracking helps monitor where vehicles are in real time, provides information on traffic and the best routes to use	0.657		
EE2	Optimal truck routing and scheduling has been seen as one of the means to help companies reduce their energy consumption	0.776	0.595	Energy efficiency
EE4	Energy consumption can be increased by driver behavior	0.712		
EE1	The amount of gas emitted, and the total energy consumed by trucks can be reduced by in-vehicle eco driving systems	0.647		
DB3	The life span of trucks heavily depends on driver behavior	0.81	0.582	Driver behaviour
DB4	Driver training works – it can save the business money	0.756		
	Operational performance			
OPC3	Fuel cost per km has been reduced over the past three years	0.856	0.914	Operations Maintenance
OPM3	Planned maintenance programs are in place for all our trucks	0.787		
OPC5	The total number fuel litres bought for the past three years has reduced	0.727		
OPM1	The rate of tyre replacement has reduced over the past three years	0.716		
OPC6	Tyre life span has improved over the past three years	0.713		
OPC4	Swiftness of identifying areas that need urgent attention has improved in the past three years	0.662		
OPM4	Total number of litres of oil bought in the past three years has reduced	0.599		
OPM5	Driver training scheme and behavior have improved in the past three years	0.57		
OPC1	Truck utilisation has improved over the past 3 years	0.501		
OPR2	Delivering cargo at the right location has improved in the past three years	0.837	0.86	Operations Reliability
OPR1	Information sharing with our customers has improved in the past three years	0.804		
OPR4	Customer service plan has improved for the past three years	0.779		
OPR3	On-time cargo delivery has improved over the past three years	0.76		
OPF3	Truck acquisition policies have changed to energy efficient models for the past three years	0.869	0.801	Operations Efficiency
OPF4	Satellite tracking technology systems are installed in all trucks for optimal routing to reduce operational cost	0.77		

4.3 Relationship between ESPs and operational performance

The study sought to establish the relationship between ESPs and OP among trucking enterprises. Each of the two constructs had three variables thus making it difficult to test the relationship through regression techniques, hence the choice of canonical correlation analysis (CCA) to establish the relationship. The canonical correlation coefficient measures the strength of the association between ESPs and operational performance. The CCA was used because it denotes the top level of gross linear modelling (GLM) and can test a relationship in situations where both the dependent and independent constructs have multiple variables [30,31]. CCA was conducted to ascertain the relationships or significant canonical variates that help justify the existence of a relationship between the two constructs. The Wilk's lambda (ʎ) was chosen because of its general applicability [28,32,42], however, it is important to note that all the other tests are statistically significant. Wilk's ʎ =0.71515, F=4.71540 and P=0.000 (Table 5) proved that the model was statistically significant, though it explained about 29% of the variance.

Table 5 Test statistics

Test Name	Value	Aprox. F	Hypoth.DF	Error.Df	Sig. of F
Pillais	0.30400	4.51032	9.00	360.00	0.000
Hotellings	0.37202	4.82244	9.00	350.00	0.000
Wilks	0.71515	4.71540	9.00	287.33	0.000
Roys	0.22356				

Three canonical correlation functions were noted with the first canonical correlation coefficients of 0.47282, an explained variance of 77.39476 percent and an eigenvalue of 0.28792 as illustrated on Table 6. Thus, confirming that the hypothesis is correct, that is, ESPs and operational performance are positively correlated. Sherry and Henson [33,35] claimed that functions that describe a sensible amount of variance among variables should be interpreted. In addition, function 1 explained a substantive 77.4% of the variance and should be considered for further interpretation.

Table 6 Eigenvalue and canonical correlation functions

Function No.	Eigenvalue	Pct.	Cum. Pct.	Canon Cor.	Sq. Cor
1	0.28792	77.39476	77.39476	0.47282	0.22356
2	0.05420	14.56819	91.96295	0.22674	0.05141
3	0.02990	8.03705	100.00000	0.17039	0.02903

The examination of the dimension reduction helped in testing the statistical significance of the hierarchically arranged functions. The examination confirmed that the roots 1 to 3 F (9; 287.33) = 4.72; (P<0.05); Wilk's lambda (ʎ) (0.71515) was statistically significant and was considered for interpretation as well as root 2 to 3. The results are illustrated on Table 7.

Table 7 Dimension correlation function

Roots	Wilk's L	F	Hypoth.DF	Error.DF	Sig.of F
1 to 3	0.71515	4.71540	9.00	287.33	0.00
2 to 3	0.92105	2.49762	4.00	238.00	0.043
3 to 3	0.97097	3.58790	1.00	120.00	0.061

To establish the relationship between ESP and OP, the standardized coefficients, communalities, and structure coefficients corresponding to the first and second functions were analysed as presented in Table 8. The function was chosen because they fulfilled the criteria regarding statistical significance and amount of variance explained [33,35].

Considering the standardised coefficients of function 1, operations maintenance (0.60359), operations reliability (-0,65932) and operations efficiency (-0.91282) reveal a significant amount of the relevance of the dependent variables in the relationship, although operations efficiency depicts an inverse magnitude. Considering the standardised coefficients of the independent variables for function 1, advanced technology (0.85568) was the most relevant, while and driver behavior had a weak negative relationship with the dependent variables. The energy efficiency (0.00717) variable was the least relevant in this relationship.

The structure loadings (r_s) show significantly high loadings for function 1, which depicts a negative relationship between operations performance and the canonical variables. Operations reliability (rs = -0.63385) and operations efficiency (rs =-0.80661) were noted as the most relevant dependent variables all loading on function 1. Driver behavior (rs = -0.52424), and advanced technology (rs = -0.88322) were the most relevant predictor variables based on their correlations with the canonical variates and confirmed the negative relationship (see Table 8). The canonical effect (R_c^2) for function 1 is observed to be 22.356.

Table 8 Canonical solution for ESP and OP

	Function 1			Function 2			
	Coeff	r_s	r_s^2	Coeff	r_s	r_s^2	h^2
Operations maintenance	0.60359	-0.25547	6.527	1	0.82045	67.314	73.341
Operations reliability	-0.65932	-0.63385	40.177	-0.67005	-0.0082	0.0067	4.1837
Operations efficiency	-0.91282	-0.80661	65.062	0.18094	0.54844	30.079	95.141
R_c^2			22.356			5.141	
Driver behaviour	-0.47084	-0.52404	27.462	-0.59233	-0.45063	20.307	47.769
Advanced technology	-0.85568	-0.88322	78.008	-0.00495	0.25476	6.490	84.498
Energy efficiency	0.00717	-0.34763	12.085	0.9055	0.81098	65.769	77.854

The communalities (h^2) showed that some of the variables were relevant and useful, while others were not. Communalities above 45% are claimed to be giving a solution to the problem in question [33,35]. The dependent variables (operations maintenance, and fuel efficiency) had communalities values above 70%, similarly, advanced technology and energy efficiency also had values above 70% for the independent variables revealing the significance of the four variables in the relationship. The use of CCA as a statistical method helped establish the relationship between ESPs and OP of trucking companies. Function 1 showed operations efficiency as key response factors of OP, while advanced technology was the most relevant independent variable. The results for function 1 also imply that only a single relationship dimension exist between ESPs and OP based on the canonical effect. Therefore, there is a relationship between ESP variables and OP variables based on the high structure loadings. Theoretically, advanced technology increase should result in operations reliability and efficiency, but the model depicts an inverse relationship [36]. The complexity of the technologies associated with green transportation makes them costly, thereby contributing to non-implementation, as most companies consider the costs in direct comparison with the benefits to be attained. It might be important to examine the specific technologies that are needed to improve reliability and fuel efficiency.

4.4 Challenges of implementing ESPs

Ascertaining the challenges faced by trucking companies when implementing the environmental practices was one of the research objectives of this study. The challenges related to implementation of ESPs among the sampled enterprises were classified into low-level challenges, moderate challenges and high-level challenges as illustrated in Table 8. Various challenges were noted in the literature and this question sought to find out how the respondents would rank the challenges in the order of importance. From the results depicted on Table 9, most respondents 88.7% of the firms ranked financial challenges as a high-level, implying that it is a major impediment, followed by technical challenges which might be related to the difficulty of obtaining the relevant skills within the industry. Lack of the relevant information regarding green transportation was considered a low as well as moderate challenge thus requiring government to create more awareness. The policy, market issues as well managerial and organizational issues were considered low level challenges. The result might imply that the non-implementation of ESPs could be because of lack of funding and/or technical expertise.

From the result, one might conclude that financial challenges are huge because the implementation of any ESP comes with a financial outlay. The reason why technology was ranked second in the order of importance could be linked to the ever-changing technologies, meaning companies will need to always outsource expertise in this area, thereby causing more financial and technical challenges. The results might also imply that, despite having technical expertise and being knowledgeable about the policies, faced with inadequate finances to fund implementation of environmental practices could remain a big challenge.

Table 9 Challenges of implementing ESPs

Variables	Low	Moderate	High	Total
Financial Challenges	5.6%	5.6%	88.7%	100.0%
Technical Challenges	24.2%	29.0%	46.8%	100.0%
Lack of Information	41.1%	35.5%	23.4%	100.0%
Policy and market issues	53.2%	15.3%	31.5%	100.0%
Managerial and organisational challenges	71.0%	12.9%	16.1%	100.0%

5 Discussion

The main objective of this study was to establish the relationship between ESPs and OP among trucking companies. The ESPs activities among trucking firms include enhancing driver training to achieve optimal driver behaviour, implementation of advanced technologies such as telematics for routing and scheduling, as well vehicle tracking and fuel monitoring as well as energy efficiency initiatives that require adopting fuel economy engines, electric or hydrogen trucks. The findings reveal that majority of the trucking firms are implementing ESPs to a moderate or high extent. The finding aligns with the [17] which developed a 30-year green transport strategy that requires operators to implement initiatives to lower GHG emissions. Some on the green transportation activities identified in the strategy include application of intelligent transportation technologies, fuel economy and energy efficiency. It is established in this study that the implementation of ESPs has a one-dimensional inverse relationship with operational performance. Advanced technology (AT) was found to have the strongest relationship with OP, although it was inverse. This finding disagreed with [37] who observed that AT has a significant positive relationship on logistics and transport operations. The likely explanation would be that sophisticated technologies, such as trailer tracking, remote diagnostics technologies, and dynamic routing, require high initial capital outlay in terms of the installation equipment as well as skills, which in turn increases operational cost. The majority of the sampled enterprises were either small or medium in size implying the huge financial challenges SMEs face, thus, making it difficult for them to invest in the advanced technologies related to green transportation [21].

Energy efficiency has an inverse relationship with OP, implying that while trucking companies need to ensure all measures are in place to attain high levels of energy

efficiency, the measures are likely to be costly and discourage especially the medium, small and micro firms. While [14], observed that fuel accounts for a large share of logistics operating costs in the freight industry, the measures to ensure high energy efficiency are costly and discouraging to profit seeking enterprises. In addition, [12] also observed that technological advances enhance fuel efficiency of freight vehicles and reduce the carbon content of the fuel used, however, the sampled enterprises of which many are small or medium might find it difficult to invest in these technologies. This then implies that trucking companies need to incorporate technologies that aid energy efficiency and reduction in GHG emissions. In line with this, [17] also argued that shorter time frames for vehicle replacement play an important role in fuel efficiency, thus implying that trucking companies need to have better scrappage policies based on the number of kilometers travelled as opposed to the age of the trucks.

The operational performance construct was divided into three metrics viz. maintenance, reliability and efficiency. Operations efficiency and reliability were established as the most relevant response variables. The research findings highlight costs related to repairs, breakdowns, idle time, low utilisations, and generally poor fleet management as key determinants operational performance. This is confirmed by [3], who claimed that fuel costs had greater influence than other variables on the overall performance of the transport industry. The results also imply that trucking companies need to closely monitor their operational reliability in terms meeting their clients requirements consistently through effective routing and scheduling. While reliability is key component of a transport service quality it would be inversely related to environmental sustainability initiatives based on the amount of capital investment required to achieve the required service levels. Further, a by [6] affirms that advanced technologies help in keeping both the transport operator and the shipper satisfied, resulting in improved operations reliability. It is also important to note that operations reliability can be affected by congestion in the cities which result in delayed deliveries, in such cases real-time sharing of traffic data sharing technologies can be of help to assist in rerouting trucks to ensure high delivery reliability as well as reduced costs and GHG emissions due to congestion. This implication is supported by the [22], which argued that advanced technologies were in minimal use by road freight enterprises. Therefore, it is argued in this paper that the implementation of sustainable practices such advanced technologies, energy efficiency and better driver behaviour is not likely to result in high operational performance in terms of efficiency and effectiveness. As such, the implementation of sustainable practices should be done as a social good by responsible enterprises without a major focus on profits. In addition, it is critical to highlight that the financial burden associated implementing the sustainable practices makes it very difficult for SMEs in the trucking sector, this requires government to introduce tax rebates or any form of incentives to encourage compliance with the relevant environmental laws.

While the results reveal that many of the sampled enterprises had implemented the environmentally sustainable practices to some extent, they equally faced myriad challenges such as financial, technical expertise and lack of relevant information related to environmentally sustainable practices. The finding implies that managers of road freight enterprises should be able to overcome these challenges before they can successfully implement the said green practices.

6 Conclusion

We establish that majority of the enterprises involved in trucking business in South Africa are SMEs and are aware of the negative impact of fossil fuels and GHG emissions to the environment. Many of these firms also implement environmentally sustainable practices to some extent, but within the confines of their financial and technical capabilities. Within the trucking industry it is observed that implementation of sustainable practices does not result in improved operational efficiencies and effectiveness. The finding implies that trucking firms should implement environmentally sustainable practices as a social good as opposed to for profit. The high competition and low margins in the road freight sector is likely to discourage small and medium firms from participating in environmental sustainability due to financial and technical challenges. This calls for government agencies to consider lowering tax on environmentally friendly technologies, fuels, vehicles and associated training or expertise services to encourage adoption for the social good. Action from government is likely to result in moving closer to achieving UN SDG 11 related to sustainable transportation.

Managers in the trucking sector are informed that the implementation of sustainable practices is not likely to result in improved operational performance. In addition, the implementation of sustainable practices requires financial and technical resources. Thus, implementation of sustainable practices should be a strategic decision that requires to be well thought before and resources allocated in the long-term to avoid operational inefficiencies.

The findings of the study are limited to the trucking industry in South Africa and may not be generalised for all countries in Africa. The data was also collected cross-sectionally. In future a multicounty longitudinal study would help compare the various regions to establish the relationship over time. Data from developed countries where the implementation of sustainable practices is mature would help to understand the relationships better in the future.

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Differentiation of stocks by the ABC approach in the synergy of the order penetration point of the logistics chain
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Differentiation of stocks by the ABC approach in the synergy of the order penetration point of the logistics chain

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Keywords: logistic chain, order penetration point, costs, optimization, ABC method.
Abstract: This research summarizes the results of the scientific discussion about the logistic chain and its order penetration point and influences on the costs of stocks. The main goal of this article is to point out determining the order penetration point of the logistics chain and differentiation of stocks according to importance from the point of view of optimizing costs and securing liquid financial resources. The object of the research was the industrial company. In this research, methods focused on using ABC analysis and Pareto analysis. The results of this research show 5 order penetration points (OPP1-OPP5) and a Push and Pull system to manage material flows for order penetration point of the logistics chain at the customer's order point. Cost optimization was solved by classifying the stocks into categories A, B, and C which is an important fact for planning and inventory management. ABC method divided 100 types of inventories with costs €5 million into categories A, B, C. Critical types of stocks in category A represents the group of stocks 38,92,7,52,13,54,90 that were reduced. This reduction of critical stocks led to the release of funds tied up in stocks. This change has a positive effect on the financial side of the company's cash flow – financial flows.

1 Introduction

Inventory represents the assets of a business and forms an important element of supply- customer chains that ties up a significant number of financial resources. Inventory, on the one hand, ensures the required level of customer service – continuous flow and enough inventory of stock items in the warehouse, on the other hand, the size of the inventory should be optimized so as not to allocate too many funds to the inventory because optimal stocks are based for lean production and effective information logistic system [1]. Supply chain management creates synergy between the optimization of stocks and checking the suppliers [2].

The goal of this paper is to determine the order penetration point disconnection point of the logistics chain and differentiation of stocks according to importance from the point of view of optimizing costs and liquid financial resources. Inventory management is part of supply chain management. Companies need strategy inventories in warehouses to fulfil customer demand. These strategy inventories create costs and it means financially no liquid items [3]. Inventory management partially mediates the relationship between managerial competence and financial performance [4]. The logistics chain (Figure 1) is therefore a sequence of individual elements through which the material flow passes from the supplier of raw materials to the final customer [5]. The mapping and quantification of material, information, and financial flows and their visualization is the basis for understanding and systematic work with the so-called disconnection point of the logistics chain.

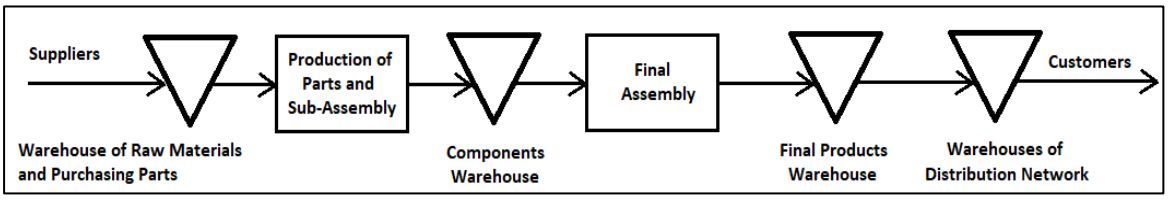

Figure 1 Logistics chain (own source)

Differentiation of stocks by the ABC approach in the synergy of the order penetration point of the logistics chain

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The horizontal structure (Figure 2) of logistics management is the division of the material flow into a part managed according to stocks, the production program, based on demand forecasts and managed according to customer orders [6]. The inventory control system based on the stock level gives the impetus to place a production order or to place an order for stock replenishment now when the stock has fallen below the so-called signal or order level [7]. Control according to the program is an extension of the previous system by a time interval. The impulse, the creation of which is dependent on the immediate level of stocks, is here replaced by a time program - a stock replenishment plan [8]. Based on the demand forecast, the immediate time course of the immediate stock is determined. The necessary data for entering production orders and/or orders is then derived from this process. When managing according to customer orders, assembly, production, or even the prior procurement of some materials and parts begins only after the receipt and confirmation of the order.

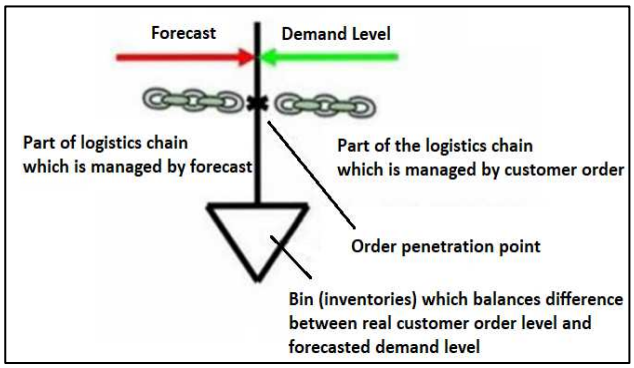

Figure 2 Order penetration point of the logistics chain (own source)

The limit between the two parts of the material flow forms the point where the logistics chain is disconnected by the customer's order. At this point, independent demand is transformed into dependent demand. The location of the decoupling point indicates how deep independent demand that is, customer orders penetrate the company's material flow.

2 Methodology

The goal of this paper was to point out and determine the order penetration point of the logistics chain and this order penetration point is analysed first by characteristics and then by structure and material flow management. Results are presented in the analytical part of this paper. Since the order penetration point in the logistics chain also affects the number of costs, we used the ABC method of inventory differentiation according to significance and importance to optimize costs. The principle of ABC analysis (Figure 3) is derived from the Pareto rule, defined by the Italian economist Vilfredo Pareto. Only 20% of the possible causes cause 80% of the consequences. Pareto's law is therefore a method that formulates the basis of inventory management. It is a method of classifying the product portfolio according to various criteria of importance and ultimately makes a large product portfolio transparent.

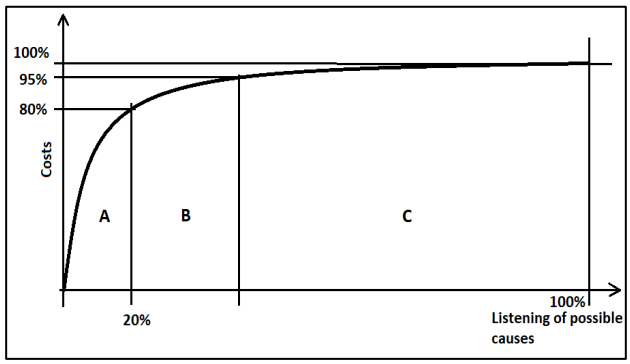

Figure 3 Pareto analysis and Lorenz curve (own source)

The principle of ABC analysis defines 3 categories of inventory: inventory category A, inventory category B, inventory category C. Group A includes a relatively small number of elements with a high share of the total value, the share of B elements corresponds to its number, and group C includes the remaining elements of the set with a small share of the total value. Group C tends to be the most numerous. Files of this type can be encountered very often. Based on the value expression of stock and quantity, we classify group A - cost 80%, quantity of stock 20%, group B - cost 15%, stock 30%, group C - cost 5%, quantity of stock 50%.

3 Result and discussion

This order penetration point is analysed first by characteristic and then by structure and material flow management.

The order penetration point is therefore the place in the logistics chain in which the dispersion of demand for the given product is balanced. The order penetration point is the place where the customer's order "runs in" and thus starts and controls the subsequent material flow. The order penetration point by customer order always refers to a certain combination of product and market. This means to a certain product (or family of products, product line) and to a certain circle of customers in a certain territory. Determining the location of the order penetration point in the material flow is a very important decision of the company's management – more precisely material flow management. The disconnection point by the customer's order is an important location of the disconnection stock, which ensures the satisfaction of independent demand. Random fluctuations in customer demand are captured in it through the safety stock. Stochastic methods are used to control the replenishment of inventory at the order penetration point.

The order penetration point of the logistics chain "disconnects" the entire logistics chain into two parts: to the part controlled by the plan, which is burdened by the fact of demand uncertainty, the consequence of which is the necessity to maintain a safety stock at the order penetration point, to the part driven by specific demand, which is characterized by the fact that there are no stocks in the system to manage material flow that are at risk of "unsaleability"; everything here is only a matter of capacity balancing and planning. The order penetration point by customer order always refers to a certain combination of product and market. This means to a certain product (or family of products, product line) and to a certain circle of customers in a certain business territory. Determining the location of the order penetration point in the material flow is a very important decision of the company's management. We have analysed the possible ways of the order penetration point of the logistics chain and describe 5 ways for the order penetration point in the logistics chain (Figure 4).

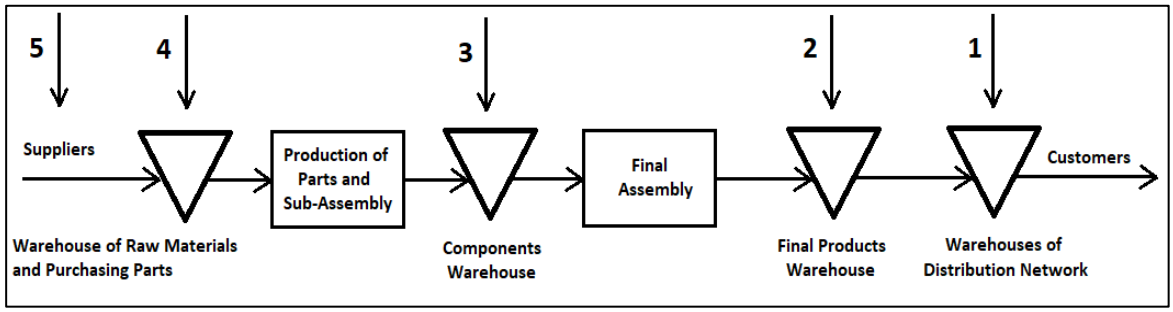

Figure 4 Possibilities of order penetration point of the logistics chain (own source)

OPP1 – order penetration point in distribution warehouses, final products are shipped to the network of distribution warehouses, and to customers. This order penetration point assumes the existence of a distribution network. The customer's order enters the distribution warehouse.

OPP2 – order penetration point in the warehouses of finished products; the final products are concentrated in one place in the company. The customer's order penetrates the warehouse of finished products of the production plant, or into the central warehouse, from where the products are then dispatched.

OPP3 – order penetration point in assembly warehouses prior to final assembly represents the location of the order penetration point somewhere within the manufacturing and assembly process.

OPP4 – order penetration point in the warehouses of raw materials, materials, and semi-finished products at the manufacturer, only raw materials, materials, and purchased parts are stored; the customer's order penetrates up to this stock. Production starts only based on a specific order; each order is usually implemented as a separate production order.

OPP5 – order penetration point in the supplier's warehouses, stocks are not permanently maintained at all; the procurement of raw materials, materials, and purchased parts begins only after receiving the customer's order. Each order represents a specific project.

Characteristics of order penetration points in the logistics chain (Table 1).

Table 1 Order penetration point characteristic (own source)

Point	Place	Activity
OPP1	Distribution warehouses	Production and expedition to the warehouse
OPP2	Warehouses of finished products	Production to the warehouse
OPP3	Warehouses prior to final assembly	Construction to order
OPP4	Warehouses of raw materials	Production to order
OPP5	External warehouses	Purchase and manufacture to order

The order penetration point by the customer order separates areas of the material flow with a different management method and thus also with different requirements for planning methods and with a different nature of decision-making (Figure 5). **"Downstream"** material flow control - from the point of disconnection to the market, activities are managed based on received confirmed customer orders. Controlling the material flow **"upstream"** from the decoupling point to the suppliers is

activity control based on plans compiled based on an independent demand forecast.

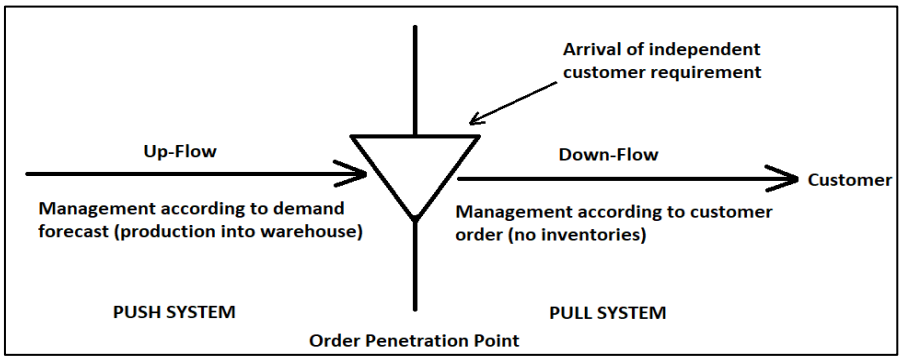

Figure 5 Order penetration point of the logistics chain at the customer's order point (own source)

"Downstream" material flow control: the main decisions concern the coordination of all activities for specific orders. Allocation of capacities is determined by accepted orders. Production or assembly batches are usually equal to the size of the order. In this area of material flow, production is usually controlled using PULL systems. **"Upstream"** usually, a master production plan is drawn up, which represents the production program for replenishing the stock of items at the order penetration point by the customer's order. Based on this plan, the dependent need for subordinate items in the materials, and parts are then calculated. Capacities are planned for estimated future demand. It is produced in batches; the effort is to make the best possible use of capacity. In this area of material flow, production is mostly managed using PUSH systems.

When determining the optimal location of the disconnection point for the customer's order, it is important to monitor factors such as the time interval of delivery to the customer, the number of costs associated with delivery, the speed of processing the order, the provision of service delivery services, which ultimately has a significant impact on customer satisfaction.

The further the order penetration point is located from the customer, the more the cost of holding safety stock is saved. On the other hand, however, the overall reaction time to a customer's order is, on the contrary, longer the further the order penetartion point is from the customer. The closer the order penetration point is to the customer, the greater the risk of unsalability and high inventory holding costs. On the other hand, the more the production has the character of custom production, the less the mentioned risks are, but the reaction to specific customer requirements is slower, and the production costs increase (Figure 6).

For optimizing stocks in industrial companies is important to combine the ABC method with the EIQ method (entry, item, quantity). This combination aims to understand the relationship between the order types and quantities. It helps to clarify the customer's order quantity and the proportion of orders [9]. Implementation of several inventory control methods (ABC, XYZ, EIQ, Pareto analysis) is efficient to improve the smooth operation of trading companies and industrial companies to solve problems such as inventory shortages and on the other hand excess unrequired inventory [10]. The EOQ model, SIM model, SC inventory model, and SC structure model are models for optimizing stocks. Those models sustainable inventory management in supply chains. Those models are the instrument for new research in the inventory areas for the future [11].

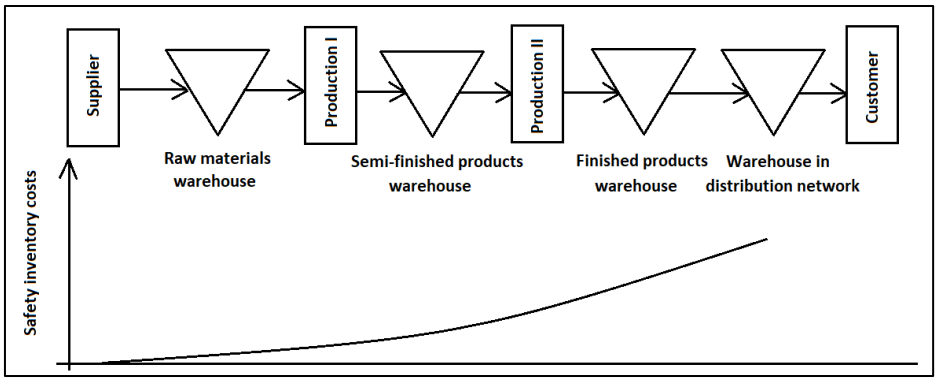

Figure 6 Amount of costs to the location of the order penetration point of the logistics chain (own source)

The inventory management system of flows is a very essential component for each company. Inventory creates assets of the company and the most important resource of the production. The inventory management and control system relates to methods of ABC analysis, VED analysis, and EOQ analysis [12]. In modern business today, companies that hold large numbers of inventory items do not find it economical to make policies for the management of individual inventory items. The method of grouping and inventory control available in traditional ABC has a lot of disadvantages which were solved in the new innovative model ABC. This ABC model is solved by the mathematical model by the Benders decomposition and the Lagrange relaxation algorithm has an objective function to maximize the net profit of items in stock. Limitations such as budget and even inventory shortages are considered too [13].

Application of ABC method and Pareto analysis of stocks

We applied ABC analysis in an industrial enterprise, in which the order penetration point of the logistics chain is monitored according to the OPP5 type. There are 100 types of inventories with a value of €5 million in the external warehouse, which tie up the company's financial resources, and the company has a problem with cash flow and the liquidity indicator. This problem was solved by optimizing stocks in warehouses according to the ABC method, which determined A, B, C categories of stocks (Table 2) according to the amount of costs and the number of stock types stored. Category A consists of 10 types of stocks, which means 10% of the ratio of stocks from the total stocks in the company, which represent a high value of supply and storage costs at the level of 80% of total costs, which represents €3.9 million, which tie up the company's financial resources, thus affecting solvency of the company.

Table 2 ABC classification – method (own source)

Category	Number of type of stocks	Structure of stocks (%)	Costs of stocks (€)	Structure of costs (%)
A	10	**10%**	3 999 425	**80%**
B	36	**36%**	741 263	**15%**
C	54	**54%**	259 312	**5%**
SUM	100	100%	5 000 000	100%

Given that category A represents critical stocks, it is necessary to analyse them in detail. We found out which specific types of stored stocks are in category A from financial accounting, we determined the amount of costs related to individual types of stored stocks. From the 10 types of items, it is possible to determine problematic items based on Pareto analysis. In stock category A, the 10 item types were as follows (Table 3): 38,92,7,52,13,54,90,14,12,30. We assessed these inventory items from financial accounting on accounts 501 01-501 10 analytical records in the company's accounting.

Table 3 Pareto analyse of Category A (own source)

Type of stocks	Costs of stocks (€)	Structure (%)	Cumulative structure (%)
38	525790	**13**	13
92	448874	**11**	24
7	443876	**11**	35
52	435722	**11**	46
13	427940	**11**	57
54	416191	**10**	67
90	392277	**10**	77
14	384605	**10**	87
12	368011	**9**	96
30	156139	**4**	**100**
SUM	3999425	100%	

In order to calculate the critical items, it was necessary to arrange the types of inventory from the highest cost item to the lowest cost item, then to determine the share of individual items of inventory in percentage terms, while the total share is 100%, the share determined in this way was then accumulated in order to be able to graphically represent the Lorenz curve, which sets us critical inventory cost items. Based on the graphic representation, we will determine the stock value with a column chart as a Pareto analysis and insert the cumulative value of the percentage expression of the individual types of stock into the chart. At the point where the Lorenz curve intersects 80% on the y-axis, the perpendicular to the x-axis will represent the critical inventory type interval (Figure 7).

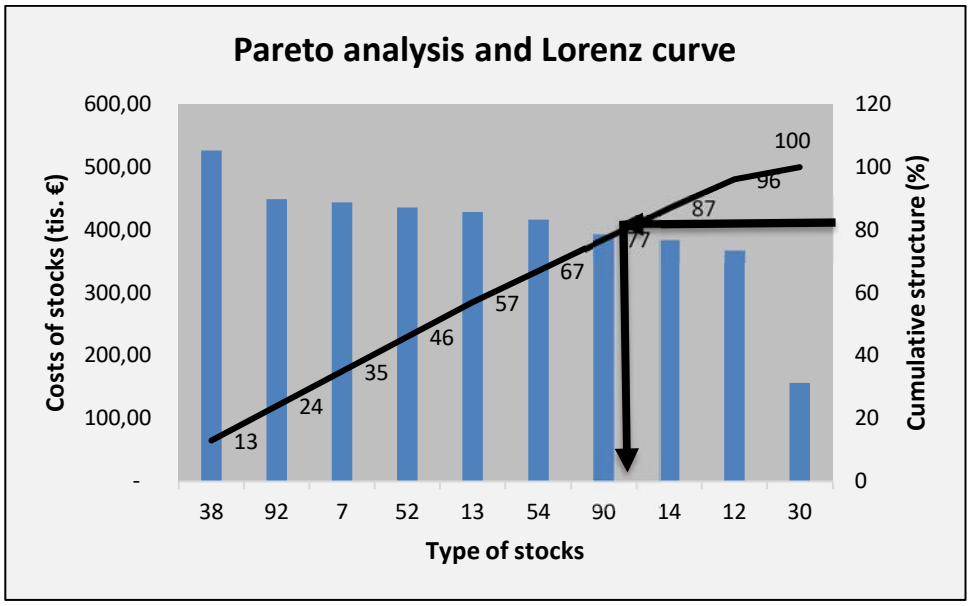

Figure 7 Pareto analysis and Lorenz curve (own source)

Based on the Lorenz curve, we can conclude that the critical types of stocks in category A represent the group of stocks 38,92,7,52,13,54,90. Within this category A, the 80/20 rules of inventory group 14,12,30, which represent costs of €156,139 to €384,605, do not belong to the Pareto. Costs in other inventory groups are growing and represent a tie-up of financial resources in the company. Systematic inventory management practices (IMPs) introduce an important and effective success factor for industrial companies [14]. The dynamic development of Industry 4.0 is focused on the implementation of new technologies that implement new methods, and instruments for inventory management systems [15].

4 Conclusions

Optimum inventory management in the company is an important part of the strategic management of the company because supply management is the main business process in the value chain, on which other processes such as production, sales, service, etc. depend. Stocks represent the company's property, which is gradually consumed according to the requirements of the production process and whose value is gradually reflected in the value of the finished product. The results of this research were to point out determining the at-order penetration point of the logistics chain and differentiation of stocks according to importance from the point of view of optimizing costs and securing liquid financial resources. Results of this research shows on 5 order penetration points (OPP1-OPP5) and Push and Pull material flow management system for order penetration point of the logistics chain at the customer's order point. Cost optimization was solved by classification the stocks in category A, B, C that is important fact for planning and inventory management. ABC method divided 100 types of inventories with costs €5 million into categories A, B, C. Critical types of stocks in category A represent the group of stocks 38, 92, 7, 52, 13,54, 90 that were reduced. This solution introduces one alternative the release of funds tied up in stocks. This alternative has a positive benefit on the financial side in the area of cash flow. Using Pareto analysis for stock optimization is an instrument, which means benefits in material flow management.

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Strategic enhancement of Zakat collection and distribution in philanthropic institutions: integration of SERVQUAL, Kano, and QFD
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Strategic enhancement of Zakat collection and distribution in philanthropic institutions: integration of SERVQUAL, Kano, and QFD

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Keywords: service quality, Kano, SERVQUAL, quality function deployment, philanthropic institutions.
Abstract: Zakat philanthropic institutions have a pivotal role in fund collection and distribution, yet they haven't realized their full potential primarily due to diminished public trust. Addressing this challenge requires strategies to elevate service quality. This study introduces an integrated method combining SERVQUAL, Kano, and Quality Function Deployment (QFD) to optimize Zakat service quality. Out of twenty-one service attributes evaluated, fourteen were identified as pivotal for strategic enhancement, spanning areas like information management, human resources, and product diversification. Utilizing the QFD framework, these attributes were transformed into actionable quality improvement measures. The suggestions for quality improvement measures include refining website functionalities, ensuring consistent and engaging information dissemination, comprehensive employee training, introducing e-wallet options, and expanding student loan provisions. By integrating SERVQUAL, Kano, and QFD, this research offers a holistic assessment approach, emphasizing only those service aspects that truly resonate with donor satisfaction. The findings and recommendations present immediate actionable insights for institutions aiming to augment zakat collection and distribution efficacy.

1 Introduction

Philanthropic institutions are institutions that do not seek profit in the implementation of their programs. Establishing a philanthropic institution aims to enhance beneficiaries' long-term and sustainable welfare. This indicates that the implementation of the channelled program is not limited to satisfying momentary requirements but also includes those that are advantageous for life. In Islam, charitable giving takes the form of Zakat, Infaq, Sadaqah, and Waqf (ZISWAF) [1]. A zakat institution is one type of philanthropic organization.

Zakat is an asset that must be spent by a Muslim or business entity of 2.5% if the assets owned are equal to or greater than 85 grams of gold (nisab) in 1 year and be given to people who are entitled to receive zakat in Islam or called mustahik [2]. People who can pay zakat are called muzakki, and people who collect and distribute it are called Amil. Infaq is a person's sincere gift in the form of material that can be given to anyone, whether in need or not. Sadaqah is a gift given sincerely in material and non-material goods, such as smiling to fellow Muslims and doing good to others. Meanwhile, waqf is a type of gift in the form of goods that cannot be inherited and is maintained so that its value does not decrease and the benefits can continue to be given for the public interest [3].

Indonesia has tremendous potential for collecting zakat. The results of a study by the Badan Amil Zakat Nasional (Baznas) Center for Strategic Studies in 2021 the realization of the collection of zakat funds reached 14.1 trillion from the projected achievable zakat potential of 327 trillion. This amount is not optimal because only about 4.28 percent of the projected potential for zakat has been realized [4].

The cause of the non-optimal realization of zakat fund collection is partly due to the low public trust in zakat institutions. This causes some people to prefer to give their zakat directly to mustahik, so it is not documented. Thus, the biggest challenge for institutions to increase ZISWAF fund collection is encouraging muzakki to pay ZISWAF through existing institutions [5]. This challenge requires creating innovative and creative programs and improving the quality of services, including logistics of ZISWAF distribution to show the best conditions. This condition can attract and give confidence to muzakki to channel their funds even more.

Baitul Maal of Universitas Islam Bandung (BMU), one of the philanthropy institutions that collects ZISWAF funds and social funds to be distributed for the educational needs of Universitas Islam Bandung (UNISBA) students. BMU experienced difficulties in increasing the collection of ZISWAF funds from internal UNISBA, namely lecturers, education staff, and new student infaq, as well as external, namely corporate sponsors, alums, and individuals [6]. Although BMU has distributed around 90% of its funds for student scholarships, the percentage of

students receiving scholarships is still relatively low due to the limited funds raised.

To increase the amount of ZISWAF funds received by BMU, it is important to improve service quality by creating innovative donation distribution programs and improving services according to donor needs to maintain donor loyalty to donate and increase the trust of prospective donors to entrust their ZISWAF funds to BMU. This statement is by several previous studies which say that, if the services provided are of high quality, of course, muzakki will feel satisfied and encourage them to maintain their loyalty and trust to channel their zakat through the institution [7] and can attract more muzakki to donate to a zakat institution [8].

Based on the description above, the purpose of this research is to identify service attributes that need to be improved using the SERVQUAL and Kano methods and design service quality improvements based on service quality dimensions using the Quality Function Deployment method in order to enhance service quality and sustainably increase the amount of funds raised and distributed by BMU.

Several studies have been conducted to enhance service quality in different sectors of service-oriented organizations, including hospitality [9], libraries [10], aircraft MRO [11], health services [12], universities [13], and banking [14]. These studies have employed a range of methods, such as the application of Kano and QFD techniques. A study was conducted to investigate the enhancement of service quality in entrepreneurial education service startup enterprises using the integration of SERVQUAL, Kano, and QFD methodologies [15]. The findings of the research demonstrate the potential avenues for holistic enhancement. Previous studies undertaken at zakat institutions have utilized the Structural Equation Model (SEM) methodology to propose a conceptual framework to enhance the quality of services these organizations provide [8]. However, this research did not thoroughly define the specific consumer needs.

The novelty of this research is to adopt an integrated approach by combining the SERVQUAL, Kano, and QFD methods at zakat philanthropic institutions. This method is a comprehensive solution to improve service quality and zakat collection by prioritizing donor needs and expectations as a basis for service development. This research emphasizes donor experiences and perceptions, which have not been thoroughly studied in this context. In addition, the study offers valuable recommendations and integrates the findings into operational measures that zakat charity organizations can implement. This shows that this study provides solutions that can be applied in the field in addition to its analysis.

2 Methodology

2.1 Research variables

This research uses a quantitative approach because it uses variables as the research object. The variables were derived from classifying donors' needs and wants, obtained through interviews with 10 donors who donated more funds than others. The results of the interviews were then analyzed by categorizing them based on the dimensions of service quality, which represent all aspects of a service, including the physical form and process of receiving services. The service quality variables in this study are as follows [16]:

1) Tangibles focuses on the physical aspects of a service, such as facilities and employee appearance.
2) Reliability is the ability of a company to deliver the promised service accurately and without error.
3) Responsiveness, willingness to help, and immediate response to customer requests and questions.
4) Assurance, providing customer trust and security based on employee knowledge and courtesy.
5) Empathy and willingness to understand customer problems and provide attention and care.
6) Knowledge, where the company provides information and data to generate interest in the product and facilitate decision-making [17].

Respondents were selected using purposive sampling, namely lecturers and education personnel who know BMU services. The number of samples was 79 people based on the Slovin formula.

2.2 Stages of integration 3 methods

Service quality improvement in this research will use 3 integrated methods. These methods include:

(1) SERVQUAL

The SERVQUAL method is used to maximize customer satisfaction based on identifying the gap analysis between customer expectations and perceptions of service quality [18]. The advantages of this SERVQUAL method are that it can assess the performance of a service attribute and help identify company weaknesses and strengths [19].

(2) Kano

The Kano method allows us to prioritize service quality attributes by categorizing customer needs in detail based on their influence on customer satisfaction [20]. Kano employs a model that helps classify needs and comprehend customer characteristics into six categories, including the Attractive category, which includes service attributes that customers do not expressly expect but, when met, result in high customer satisfaction. The One Dimensional category comprises attributes that, when fulfilled, lead to maximum customer satisfaction, whereas their absence causes dissatisfaction. On the other hand, must-be attributes may not directly affect satisfaction when fulfilled, but their absence greatly dissatisfies customers. Questionable attributes arise when customers are uncertain about the impact of a particular service attribute on their satisfaction. Reverse attributes yield satisfaction when not provided, but their provision decreases satisfaction. Lastly, Indifferent attributes have no significant influence on customer

satisfaction, regardless of their presence or absence [10]. The advantages of the Kano categorization are used as a consideration for strategy development and creating value to meet customer satisfaction [21].

(3) Quality Function Deployment (QFD)

QFD is a method for structuring the design and improvement of products or services by translating the wants and needs of consumers (voice of customer) and conducting systematic assessments in technical responses using the House of Quality matrix [22]. The advantages of this method can be used to improve service quality by ensuring that service quality development meets customer needs [11]. The QFD stages in a service can be done with only 3 stages, namely technical requirements with the help of the house of quality, process requirements, and quality procedures [23]. The technical requirement is a stage to translate the quality characteristics customers desire for a product or service into technical characteristics or company policies. Process requirements are a description of the process needs that need to be carried out by the company in answering consumer needs contained in the attributes of technical requirements/company policies. In contrast, the quality procedure is a technical step in the service provided in detail through the description of the company in answering the needs and desires of consumers contained in the process requirements.

(4) The integration of 3 methods

Integrating the Kano and SERVQUAL methods addresses their weaknesses and provides a comprehensive assessment of service quality attributes for management improvements [24]. The Kano method addresses the SERVQUAL method's limitations in linear perception and lack of innovation tools, while the SERVQUAL method complements the Kano method by offering quantitative values for service attributes. However, these methods lack systematic and operational tools for improvement efforts, necessitating integration with the QFD method. By integrating SERVQUAL, Kano, and QFD methods, a thorough analysis of service quality attributes can be conducted, leading to opportunities for improvement [15]. This integration also aids companies in identifying service quality attributes that maximize customer satisfaction, avoid developing unnecessary attributes [9] and effectively manage customer feedback [25]. Therefore, this research aims to utilize the integrated approach of SERVQUAL, Kano, and QFD methods.

The research focuses on identifying service attributes that need improvement based on their impact on donor satisfaction and designing quality procedures for improving the service quality of the zakat institution. The following steps are involved in this process:

1. Determining closed questionnaire questions by modifying the questions from indicators related to the variables determined through a review of previous research literature [12-14,23,26-28]. The questionnaire uses Likert and Kano scales to measure the gap between customer expectations and perceptions of service quality. Another questionnaire was developed to compare the perceived service quality between BMU and its competitors.
2. Testing the validity and reliability of the questionnaire.
3. Analyzing the questionnaire responses using the SERVQUAL and Kano methods to identify the gaps between customers' perceptions and expectations. Service attributes with negative gaps in the SERVQUAL method and classified as One-dimensional Must Be, or Attractive in the Kano method are identified as areas requiring improvement.
4. Using these identified service attributes as customer requirements or the "Whats" matrix in the House of Quality.
5. Creating the planning matrix or Part B, which involves calculating customer and competitive satisfaction performance values from the closed-ended questionnaire, determining goals and improvement ratios, conducting interviews with Baitul Maal UNISBA, and calculating adjustment importance values using satisfaction scores from SERVQUAL multiplied by the weight values of the Kano categories.
6. Developing the technical requirements or Part C by interviewing Baitul Maal UNISBA to determine the technical responses or characteristics of the institution.
7. Constructing Part D of the matrix by assessing the strength of the technical requirements' relationships with the voice of the customer using symbols (●) for strong relationships (value 9), (o) for moderate relationships (value 3), and (Δ) for weak relationships (value 1). The direction of the relationship development is also determined.
8. Creating Part E of the matrix by assigning correlation values to the technical responses, indicating the impact of one technical response on another using symbols (√√→) for a strong positive influence, (√→) for a moderate positive influence, (<blank>) for no influence, (x←) for a moderate negative influence, and (xx→) for a strong negative influence.
9. Developing Part F of the matrix by calculating the weight priorities, determining the technical benchmark and own performance, and establishing target improvement values for the technical requirements.
10. Defining the process requirements by discussing with the distribution and marketing team of BMU and determining the relationships and weight priorities for the process requirements.
11. Quality procedures are designed based on the company's responses to customer needs and desires. These procedures are developed through discussions with the distribution and marketing team of BMU,

observations of other institutions, and literature studies.

Matrix A, or the customer needs (Whats) matrix, contains service attributes identified as having negative gap values and falling into the One dimensional, Must Be, and or Attractive categories. Meanwhile, matrix C or the technical requirements matrix contains steps to improve the technical requirements of the company to respond to the needs and desires of consumers contained in matrix A. These technical requirements were obtained based on discussions with the BMU marketing and logistic departments, searching the website, and conducting literature studies. Meanwhile, the process requirements and quality procedures attributes are a form of description of the steps to improve the technical requirements of the company contained in matrix C. Thus, the relationship between matrices A and C in QFD is very close because both complement each other in designing quality services and fulfilling customer needs and wants.

3 Result and discussion

Based on the interviews and observations, 21 attributes of consumer needs and desires for service quality of zakat institutions were obtained, and then the attributes were grouped based on service quality dimensions and knowledge variables. The attributes that have been grouped are used to determine the closed questionnaire questions by finding indicators through the previous research literature, resulting in 21 valid and reliable closed questionnaire questions. The questionnaire questions are shown in Table 1.

Table 1 Research variable identification

Identification of Research Variables	Indicators	Questionnaire Question
Tangible	Availability of Waiting Room and Availability of Garbage Bins	Baitul Maal UNISBA has a spacious service room with waiting chairs.
		Baitul Maal UNISBA keeps its premises clean and has rubbish bins
	The existence of communication media in the service	Baitul Maal UNISBA has media to convey information on institutional activities, fund distribution programs, and the latest news (Websites, Bulletin, and social media).
		Baitul Maal UNISBA has customer service contacts such as live chat via phone, WhatsApp, and email to facilitate communication
	Having service products that fulfill consumer needs	Baitul Maal UNISBA has a variety of service products or donation distribution programs that can meet the needs of recipients of its services and attract donors' desire to donate, such as (Scholarship Funds, Interest-free Long-Term and Short-Term Loans, Foster Parents, Revolving Waqf Funds, Business Assistance, Assistance Funds for Village Services).
	Completeness of features on the *website*	Donors with an account on the Baitul Maal UNISBA website can see a special report of the amount of funds donors give along with the time.
Reliability	Companies provide other efforts or ways of service so that consumers do not spend much effort	Baitul Maal UNISBA provides services for ease of donation such as through payroll, interbank transfers, and e-wallets such as Dana, go pay, ovo, and payment through QR scans
	The information provided is accurate	Baitul Maal UNISBA provides information updates regarding the funds received for each ZISWAF product offered through social media websites, for the wider community.
		Baitul Maal UNISBA provides information to the public regarding the financial statements of collection and distribution through its website, and social media per month/quarter/semester/year.
	There are quick transaction status notifications and transaction reminder	Baitul Maal UNISBA provides reports on funds that have been given by donors personally via WhatsApp and email
		Baitul Maal UNISBA provides proof of transaction to donors within a maximum of 1x24 hours for donation payments that have entered the institution.
	There are quick transaction status notifications and transaction reminder	Baitul Maal UNISBA provides information on invitations to donate to institutional activities periodically through pamphlets/banners, social media, websites.

Responsiveness	Delivering what customers ask for in a timely	Baitul Maal UNISBA employees are responsive in providing answers to questions related to service programs and procedures both offline and online within 1x24 hours.
Assurance	Employee attitudes, words, and actions provide credibility	Baitul Maal UNISBA employees provide friendly and professional services that increase trust and desire to donate.

Table 1 Research variable identification

Identification of Research Variables	Indicators	Questionnaire Question
Assurance	Equal service regardless of age and position and provide a good response in receiving criticism suggestions	Baitul Maal UNISBA employees accept responses to criticism and suggestions well and do not look at the age and position of the person speaking.
	Employees can maintain the confidentiality of data	Baitul Maal UNISBA employees can maintain the personal data information of donors who do not want their names published in public reports
Empathy	Employees provide solutions or answers and appointment flexibility	Baitul Maal UNISBA employees can provide advice on service products that are by the ability/desire of donors.
		Baitul Maal UNISBA employees have flexible and free time to conduct cooperation and provide services.
Knowledge	Knowledge of the benefits of a product, and Knowledge of the system used in the product	Baitul Maal UNISBA provided knowledge about the basis and benefits of ZISWAF.
		Baitul Maal UNISBA provides information on the invitation to the ZISWAF program and knowledge of its benefits or basis in Islam on pamphlets/banners, websites, and social media.
		Baitul Maal UNISBA has a feature to calculate various types of zakat on the website.

The results of distributing closed questionnaires with a Likert scale will be processed using the SERVQUAL method which aims to determine the *gap* or gap between perceptions and expectations on service quality attributes provided by BMU at this time. The description of the *gap* calculation for attribute T1, namely "Baitul Maal UNISBA has a spacious service room and is equipped with waiting chairs" is explained in the calculation below:

1. Determining the mean value of perception $\bar{P}$ (1)and the average value of expectations $\bar{E}$ for each variable (2)

$$\bar{P} = \frac{\sum_{i=1}^{n} p_1}{n} \quad (1)$$

$$\bar{P} = \frac{178}{79} = 2.253$$

Description:
P_1 = The perception value given by the respondent for question 1.
n = Number of Respondents.

$$\bar{E} = \frac{\sum_{i=1}^{n} E_1}{n} \quad (2)$$

$$\bar{E} = \frac{260}{79} = 3{,}291$$

Description:
E_1 = Expected value given by the respondent for question 1.

2. Calculating SERVQUAL *score* results (for each variable) (3).

$$S = \bar{P} - \bar{E} \quad (3)$$

$$S = 2.253 - 3.291 = -1.038$$

Description:
S = SERVQUAL *Score.*
$\bar{P}$ = Average value of perception.
$\bar{E}$ = Average expected value.

3. Calculating the *satisfaction score* (4)

$$\textit{Satisfaction Score} = \textit{Gap} \times \text{Importance} \quad (4)$$
$$= -1.038 \times 1 = -1.038$$

Based on the above calculations of all attributes, 18 attributes have negative gap values and negative satisfaction scores, indicating that donors have high expectations for these service attributes but are currently dissatisfied with their quality. These attributes require improvements to meet donor expectations. On the other

hand, 5 attributes show positive gap values and satisfaction scores, indicating that the quality of these service attributes has already met donor expectations and provides satisfaction. These attributes only need to be maintained.

The service attributes with negative gap values highlight areas where BMU can improve, such as implementing a donation receipt reporting system, providing detailed and periodic information, offering adequate facilities, enhancing services, and increasing donor interest. Among these attributes, the one with the highest negative gap value is "Baitul Maal UNISBA provides proof of transaction to donors within 24 hours for donation payments received by the institution." This attribute indicates that BMU currently fails to provide transaction proof promptly, which negatively impacts donor satisfaction, especially for those who make donations during incidental times, or donors who make donations through payroll.

The next step is data processing with the Kano method, which aims to ensure that attributes with negative gaps need improvement. Using the Kano evaluation table, this method begins with classifying the answers to questions as *functional* and *dis-functional*. This evaluation table is used to classify respondents' answers into six categories: Questionable, *Indifferent*, *Reverse*, *Attractive*, *and One-Dimensional*. The classification results are analyzed using the *if-then* method based on the Blauths formula to get a broader view. Example calculation for the Blauths formula on the first attribute (5), (6):

$$\text{The value of} = \textbf{"}\textbf{\textit{one-dimensional}}\textbf{"} + \textbf{"}\textbf{\textit{attractive}}\textbf{"} + \textbf{"}\textbf{\textit{must be}}\textbf{"} \quad (5)$$
$$= 1 + 1 + 36 = 38$$

$$\text{The value of} = \textbf{"}\textbf{\textit{indifferent}}\textbf{"} + \textbf{"}\textbf{\textit{reverse}}\textbf{"} + \textbf{"}\textbf{\textit{questionable}}\textbf{"} \quad (6)$$
$$= 41 + 0 + 0 = 41$$

Because the value of ("one-dimensional" + "attractive" + "must be") < ("indifferent" + "reverse" + "questionable"). So, the category chosen is based on the maximum value of "indifferent", "reverse", or "questionable", so the category for attribute 1 is indifferent.

Based on the classification results with the Kano evaluation table and analysis using the Blauths formula, the "must be" category includes 10 fundamental attributes and must be fulfilled by BMU to avoid donor disappointment. If the service attributes are fulfilled, it will not increase donor satisfaction, because these attributes are basic and should be owned. These attributes pertain to communication media, service facilities, how service is delivered, and responsible management of donations such as open and detailed management of donations to the public.

The "one-dimensional" category consists of 3 attributes with a linear relationship with donor satisfaction. Fulfilling these attributes, such as providing a special report on the number of funds that donors have given because it is a form of responsibility for managing funds to donors, having a variety of service products because the distribution of funds utilized is one of the factors to make donors trust and be interested in donating, and providing proof/notification of transactions for donation payments because it is a form of responsiveness and responsibility for the funds given by donors. Failure to fulfil these attributes leads to donor disappointment.

The following classified category is the *attractive* category, which is a category that is not required to be fulfilled, but if given, it can increase satisfaction for donors because the provision of this service is more than what customers expect. If the attribute is not fulfilled, it will not cause a decrease in satisfaction levels. Attributes that fall into the *attractive* category if implemented are an effort to develop an innovation process to excel in competition. Attributes that fall into this category are related to providing knowledge for donors to increase interest in donating and responsiveness and innovation in the service process to provide high satisfaction.

Lastly, the "indifferent" category comprises 4 attributes that have no significant impact on donor satisfaction, in other words, respondents do not care about these attributes. Examples of attributes that fall into this category are not the main aspects that donors pay attention to, because some donors communicate only through *chat* without coming to the BMU office, so the service room, written suggestion box, and timely service according to donors' perceptions are not too important.

Understanding the classification of attributes based on these categories helps BMU prioritize its efforts for improvement. By focusing on fulfilling the "must be" and "one-dimensional" attributes, BMU can address the most critical areas to enhance donor satisfaction. Additionally, considering the "attractive" attributes can further elevate donor experience and satisfaction. Attributes falling into the "indifferent" category can be deprioritized as they have minimal influence on donor satisfaction.

The results of the calculation *gap value* and classification of the Kano category are adjusted by selecting service attributes with a negative *gap* value. They are included in the *must-be*, *one-dimensional*, and or *attractive categories* so that institutions can determine which service attributes need to be improved immediately. Not only that, but adjustments are also made by calculating the *Adjusted Importance* value, which is used as the value of the importance level of the attribute to be correlated with the *technical requirements* in the preparation of the *House of Quality*. The *Adjusted Importance* (AI) value is obtained in the following way (7), (8):

$$\textbf{\textit{Adjusting Importance}} = \textbf{\textit{Customer Satisfaction Score}} \times \textbf{Kano Model Value} \quad (7)$$

Description:

***Customer Satisfaction Score* (CSS) = *Gap* x Importance Level (8)**

The value of the canoe model is obtained if the attributes show categories:
Indifferent = 0, *Must be* = 0.5, *One Dimensional* = 1 and *Attractive* = 1.5

An example of a description of the calculation of the *Adjustance Importance* value for the 4th attribute because it has a negative *gap* value and has a *must-be* category:
Adjustance Importance for 4th Attribute = -9.367 x 0.5 = -4.684.

The Adjustance Importance value used is the absolute value without using the notation (-) minus.

Integrating the Kano and SERVQUAL methods identified four attributes with a negative gap value that fall into the indifferent category, indicating that improving these attributes would not significantly impact customer satisfaction. Similarly, attributes with a positive gap value in the must-be and attractive categories do not require improvement as customer expectations have already been met, so these service attributes only need to be maintained as the institution's strength. Therefore, the improvement focuses on attributes with negative gap values in the must-be, one-dimensional, and attractive categories as shown in Table 2.

Table 2 Attributes that need improvement

Customer Needs
Having media to convey information on institutional activities, fund distribution programs, and the latest news such as on (Website, Bulletin, and social media)
Having a variety of service products or donation distribution programs that can meet the needs of service recipients and attract donors' desire to donate, such as (Scholarship Funds, Long-Term Loan Funds, Interest-Free Short-Term Loan Funds, Foster Parents Funds, Revolving Waqf Funds, Business Assistance Fund, Assistance Fund for Village Devotion)
Donors who have an account on the website can see a special report of the amount of funds donors have given along with the time.
Provides services for easy donation through payroll, interbank transfers, and e-wallets such as Dana, Gopay, Ovo and payment through QR scans.
Provide updated information regarding the funds received for each ZISWAF product offered through social media and the website for the wider community.
Provide reports on funds given by donors personally via WhatsApp and email.
Provide information to the public/community regarding the financial statements of collection and distribution through the website and social media per month/quarter/semester/year.
Provide proof of transaction to donors within 1x24 hours to pay donations that have entered the institution.
Provide information on invitations to donate to institutional activities periodically through pamphlets/banners, social media, and websites.
Employees are responsive in answering questions related to service programs and procedures offline and online within 1x24 hours.
Employees can provide advice on service products that are by the capabilities/desires of donors.
ZISWAF institutions provide knowledge about the basis and benefits of ZISWAF.
Baitul Maal UNISBA provides information on the invitation to the ZISWAF program and knowledge about the benefits or basis in Islam on pamphlets/banners, websites, and social media.
Baitul Maal UNISBA has a feature to calculate various types of zakat on the website.

These 14 attributes are used as input in the House of Quality matrix, specifically in the "Whats" matrix or voice of the customer. The institution responds to these attributes by formulating technical requirements, resulting in seven technical requirements or matrix C attributes. The priority weights for these technical requirements are calculated by multiplying the adjustment importance value with the strength of the relationship between the voice of the customer and the technical requirement. A description of *technical requirements is* shown in Table 3.

The three technical requirement attributes with the highest priority weights are "Optimization of information media," "Education for donors," and "Development of website facilities." Currently, the institution has various information media platforms like Instagram, Facebook, WhatsApp, and a website, but they are not being utilized optimally. For example, financial statement information is not regularly updated on the website, and there is a lack of routine and scheduled information provision on Instagram and Facebook. It is necessary to optimize the use of information media, because the existence of an information media platform can reach potential donors broader and faster, can build awareness of potential donors regarding the institution's mission and the logistical processes involved in collecting and distributing *zakat* funds, demonstrate transparency in fund management,

rebranding, increase knowledge sharing. This will contribute to the competitiveness and sustainability of the institution in a highly competitive landscape.

Table 3 Technical requirement

No	*Technical Requirement*
1	Optimization of information media
2	Development of service products/fund distribution programs
3	Development of website facilities
4	Response speed
5	Quality of human resources
6	Completeness of service facilities
7	Education for donors

In the second phase of the analysis, the technical requirements obtained from the previous phase are translated into process requirements that address consumer needs and desires. Through discussions with BMU's distribution and marketing department, 7 technical requirement attributes were translated into 6 process requirement attributes. 2 technical requirement attributes were responded to 1 *process requirement* attribute, namely the optimization of information and education media for donors into 1 process requirement attribute, namely the presentation of educational information, consistent, transparent and always updated. The focus was on the three process requirements with the highest priority weights.

The priority weights for process requirements were calculated by multiplying the priority value of the technical requirement with the strength of the relationship between the technical requirement and the process requirement. The greater the relationship strength, the greater the process requirement's priority weight. The process requirement with the highest priority is "Presentation of educational, consistent, transparent, and always updated information." This can be accomplished by updating the website's content frequently and establishing a regular schedule for content distribution on social media platforms. The second-highest priority weight is "Addition of donation activity history and zakat calculation features to the website." This proposed new feature for BMU aims to provide a tool for calculating different types of zakat and enable donors to observe their personal donation history. These characteristics can increase donor confidence and decrease zakat calculation confusion. The third highest priority weight is for "Using a virtual assistant chat system to assist with response management." This proposed feature is novel for BMU, enabling quick responses to donor queries. Using a virtual assistant chat system to promptly resolve donor questions and provide transaction proofs, donation reminders, and timely online assistance within 24 hours is required to implement this process requirement. These findings provide BMU with valuable insights into the areas that require improvement and innovation to meet donor expectations better and enhance donor satisfaction.

The priority weight in the process requirement matrix is then used to determine the priority weight for the relationship between process requirements and quality procedures so that it can translate the company's answer to consumer needs contained in process requirements in the form of quality procedures in improving service quality. The description of the quality procedures is shown in Table 4.

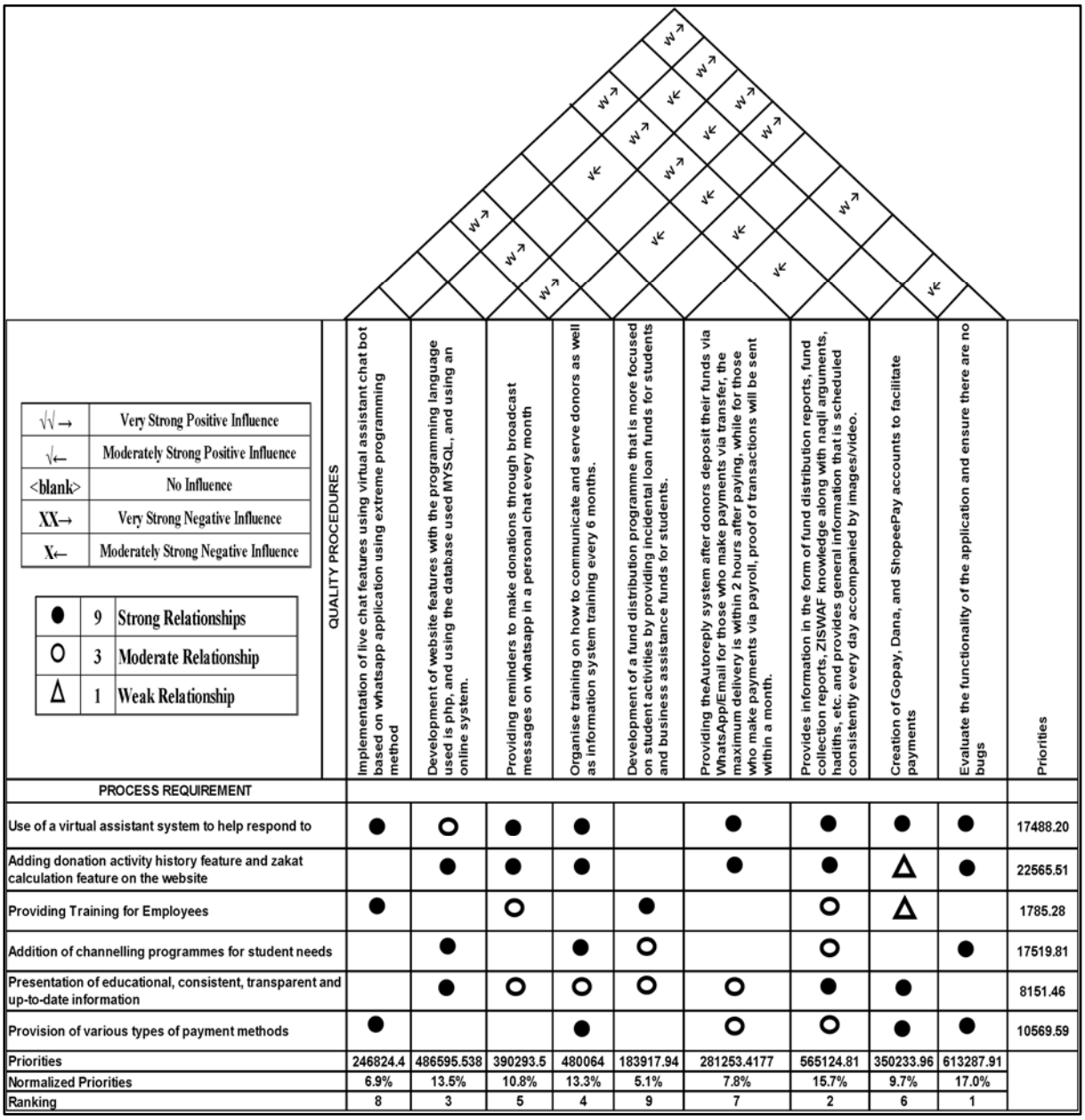
Table 4 Description of quality procedures

Quality Procedures	Reference
Implementation of live chat features using a virtual assistant chatbot based on the WhatsApp application using an extreme programming method	[29]
Development of web features with the programming language used is PHP, and using the database used MYSQL and using an online system.	[30]
Provision of reminders to make donations through broadcast messages on WhatsApp personally every month	[31]
Organize training on how to communicate and serve donors and information systems every 6 months	[32]
Development of a fund distribution program focusing more on student activities by providing incidental student loan and business assistance funds for students.	Observation of Student Needs
Provide an Autoreply system after donors deposit their funds via WhatsApp / Email. For those who make payments via transfer, the maximum delivery is within 2 hours after paying, while for those who make payments via payroll, proof of transactions will be sent within a month.	Observation of other ZISWAF Institution
Provides information in the form of fund distribution reports, fund-collecting reports, ZISWAF knowledge, Naqvi arguments, hadiths, and so on, and general information constantly planned daily and accompanied by images or video.	Observation of other ZISWAF Institution
Creation of an e-wallet to facilitate payments	
Evaluate the functionality of the application and ensure there are no bugs	[33]

Strategic enhancement of Zakat collection and distribution in philanthropic institutions: integration of SERVQUAL, Kano, and QFD

Hirawati Oemar, Ulima Alifani, Yan Orgianus

A total of 6 process requirement attributes are translated into 9 quality procedures. The translation is based on discussions with BMU's distribution and marketing department, observations of other institutions, and literature studies. One process requirement attribute is translated into 3 quality procedures, considering both customer and company voices. The use of a virtual assistant system to assist in responding to user feedback results in the implementation of three quality procedures: the application of a live chat feature using a WhatsApp-based virtual assistant chatbot using extreme programming methodology, the provision of reminders, and the implementation of an autoreply system after depositing funds. BMU's main focus is planning improvements based on the three highest priority weights of the process requirements. Figure 1 shows the quality procedure matrix.



√√→	Very Strong Positive Influence
√←	Moderately Strong Positive Influence
<blank>	No Influence
XX→	Very Strong Negative Influence
X←	Moderately Strong Negative Influence

●	9	Strong Relationships
O	3	Moderate Relationship
Δ	1	Weak Relationship

QUALITY PROCEDURES	Implementation of live chat features using virtual assistant chat bot based on whatsapp application using extreme programming method	Development of website features with the programming language used is php, and using the database used MYSQL, and using an online system.	Providing reminders to make donations through broadcast messages on whatsapp in a personal chat every month	Organise training on how to communicate and serve donors as well as information system training every 6 months.	Development of a fund distribution programme that is more focused on student activities by providing incidental loan funds for students and business assistance funds for students.	Providing theAutoreply system after donors deposit their funds via WhatsApp/Email for those who make payments via transfer, the maximum delivery is within 2 hours after paying, while for those who make payments via payroll, proof of transactions will be sent within a month.	Provides information in the form of fund distribution reports, fund collection reports, ZISWAF knowledge along with naqli arguments, hadiths, etc. and provides general information that is scheduled consistently every day accompanied by images/video.	Creation of Gopay, Dana, and ShopeePay accounts to facilitate payments	Evaluate the functionality of the application and ensure there are no bugs	Priorities
PROCESS REQUIREMENT										
Use of a virtual assistant system to help respond to	●	O	●	●		●	●	●	●	17488.20
Adding donation activity history feature and zakat calculation feature on the website		●	●	●		●	●	Δ	●	22565.51
Providing Training for Employees	●		O		●		O	Δ		1785.28
Addition of channelling programmes for student needs		●		●	O		O		●	17519.81
Presentation of educational, consistent, transparent and up-to-date information		●	O	O	O	O	●	●		8151.46
Provision of various types of payment methods	●			●		O	O	●	●	10569.59
Priorities	246824.4	486595.538	390293.5	480064	183917.94	281253.4177	565124.81	350233.96	613287.91	
Normalized Priorities	6.9%	13.5%	10.8%	13.3%	5.1%	7.8%	15.7%	9.7%	17.0%	
Ranking	8	3	5	4	9	7	2	6	1	

Figure 1 Quality procedure matrix

The priority weights of the quality procedures are obtained by multiplying the priority value of the process requirement with the relationship value between the process requirement and the quality procedures. The higher the relationship strength, the greater the priority weight of the process requirement. The highest priority is the quality procedure: "Evaluating application functions and ensuring there are no bugs." This involves evaluating the website's and other applications' functionality and conducting monthly maintenance to ensure there are no bugs or errors

in specific processes, ensuring the smooth operation of the offered features.

The second highest priority is the quality procedure: "Providing information in the form of fund distribution reports, fund collection reports, knowledge about ZISWAF, including scriptural evidence, hadith, etc., and providing scheduled general information with consistent daily updates accompanied by images/videos." Sharing information on social media platforms follows written Standard Operating Procedures (SOPs), including the content or information to be conveyed, upload timing, layout design, colour selection, and choice of media for information dissemination. Providing knowledge about ZISWAF can increase the interest of donors and potential donors in contributing their ZISWAF funds, as understanding the benefits of donating to those in need motivates people to donate more.

The third highest priority weight is given to the quality procedure: "Developing website features using PHP programming language, utilizing MySQL database, and implementing an online system." The proposed features include calculating zakat obligations for wealth and income and providing personal activity history reports of donated funds. Additionally, a feature to view financial reports within a specific time frame that can be accessed publicly. These website enhancements can be achieved by developing the website using the PHP programming language, which is open-source and freely available, and utilizing the Sublime Text 3 software for seamless integration between the interface and database. The MySQL database is chosen for its ease of use, security features, and compatibility with open-source systems. The online implementation allows administrators to make changes anytime and anywhere.

4 Conclusions

Using the Kano and SERVQUAL methods, the study's findings indicate that 14 of the 21 BMU service attributes are below donor expectations. These attributes encompass three primary areas:

1. Information Management: Enhancements in website features, fund distribution updates, payment notifications, and insightful donation-related content.
2. Service Product Development: Introduction of diverse donation payment methods and development of new donation distribution programs.
3. Human Resource Management: Fostering responsiveness and customized service suggestions among BMU employees.

We derived 7 technical requirements from these service attributes, further distilled into 6 process requirements and 9 quality procedure attributes. Implementing these procedures can bridge the identified service gaps, enhancing BMU's quality of services and donor trust. Features like an autoreply to system, live chat integration, application function evaluation, and human resource improvements are crucial.

The collection and distribution of zakat can be optimized more efficiently by enhancing website features and presenting consistent, engaging content. Incorporating an electronic wallet account is an innovative solution, facilitating both the collection and distribution of zakat. Indeed, e-wallets could represent a novel and efficient method for these processes. Furthermore, consistent training of staff and employees is paramount. Such training endeavours help enhance their skills and knowledge, ensuring the zakat distribution process runs smoothly and effectively. With the diversification of service offerings, we can increase accessibility for beneficiaries, further refining the zakat distribution efficacy. Ultimately, these enhancements work in tandem to optimize the distribution of zakat, aiming for precision and effectiveness that uplifts the community welfare.

This research uniquely integrates the SERVQUAL, Kano, and QFD approaches. Consequently, BMU has a strategic framework to boost service quality, tackling the prevalent challenge of low public trust. By emphasizing service quality aligned with donor expectations, institutions can elevate zakat collection, benefiting mustahik and paving the path for sustainable growth.

For future research, exploring practical applications to assess service modifications' efficacy and drawing comparisons with other philanthropic entities would be beneficial. The potential of emerging technologies, especially online platforms, in enhancing donor engagement deserves further exploration.

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Examination of the selection of logistics service providers

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Keywords: supply chain, logistics service provider, process design, decision making, selection.
Abstract: The selection of logistics service providers plays a crucial role in the success of an organization's supply chain management. The new industrial revolution taking place today provides solutions that prioritize the issue of quality and also raise reliability to a new level, both on the service provider's and user's sides. As businesses grow and expand, the need for efficient and reliable logistics services becomes increasingly important. This study examines how to determine the criteria for the selection of logistics service providers in the current technological environment. The choice of logistics service provider has significant implications for an organization's operations and overall performance. Optimum selection can lead to enhanced customer satisfaction, cost savings, improved efficiency, and a competitive advantage. However, poor selection can result in logistical inefficiencies, decreased customer satisfaction, increased costs, and negative impacts on organizational reputation. Hence, careful consideration and evaluation of potential service providers are crucial. The digitized environment offers a solution for accessing large-scale databases, which provide well-founded decision evaluation plans based on a large number of samples. The quality characteristics influencing the logistics parameters were examined and weighted from the perspective of customer requirements. By exploring various aspects, we aim to shed light on the intricacies of this process and provide insights that can assist organizations in making informed decisions. We attempt to make the indices that appear as bottlenecks in the specified order more efficient using an optimization procedure.

1 Introduction

Today, as a result of globalization, especially the significant cooperation of economic organizations, market competition is becoming increasingly global. Companies' competitive strategies go beyond the opportunities provided by the market within national borders and expand their production processes, strategies, and relationship systems. In the 21st century, it has become indispensable for companies to individually formulate future orientation and foresight strategies [1]. In addition, companies face new challenges such as the demand for high-quality standards, constantly changing consumer habits, a transformed market environment, and technological innovations. Taking all of this as a basis, it can be stated that essentially those companies can survive and belong to the leading edge of the competitive market, and they do not regret investing in continuous development and improvement [2]. As a result of increasing competition, both the micro and macro environments of companies have changed [3]. The assessment of business performance depends not only on internal company activities but also on their results. Currently, the recognition that supply chains, supply networks, and networks compete in the economy is becoming increasingly accepted. Excellent individual performance is in vain if a company's business partners, suppliers, subcontractors, intermediaries of its products or services, and other related actors in the supply (sales) chain do not perform adequately [4]. Based on practical knowledge, it can be established that the material flow processes taking place within the network have a strategic role; therefore, sufficient emphasis must be placed on their performance, or, in other words, their quality. The question of choosing the right service provider is detailed in this section. After reviewing the literature, it can be concluded that many researchers and professionals address the topic of logistics service provider selection methods. The multidisciplinary logistics field is supported by the fact that the process is based on mathematical methods that can be implemented to achieve effective results for the delimited topic area. Numerous proposals have been made on this topic, which examine the given issue from different perspectives. The digitization environment is important because, by providing a technological background, it generates a huge amount of data that must be usefully used during the evaluation and selection process. However, owing to the complexity of different customer needs, it can be difficult for logistics service companies to effectively understand the different ways customers value the service elements they offer. In this context, the task can be approached in such a way that, on the one hand, the

available dataset and developed decision-making method help the company using the service in choosing the right service provider, and the service provider is also a benchmark point, which provides feedback on its performance and the parameters within which the intervention should be made to maintain its market position. To judge the success of a process, we inevitably run into the requirement of measurability. In general, it can be stated that a well-developed method for the evaluation of the logistics service provider can increase the possibility of success. In many cases, the unmanageability of the large available data and information set and the lack of a measurement system can lead to an incorrect assessment of consumer or end-user expectations, which is why it is important to develop and apply a correct and well-applied criteria system. It is also necessary to develop a model that immediately reflects the impact of changes, although this impact only shows the degree of importance of the criteria. Therefore, the developed model must cover all sectors, including production and services, and measure them efficiently and effectively [5].

2 Creation of a model suitable for evaluating and choosing a logistics service provider based on multi-criteria decision-making methods

When choosing logistics service providers today, the following are the basic aspects:

- a wide range of activities provided by the logistics service provider (R-S-T activity, creation and dismantling of unit loads, product identification, collection and classification, etc.),
- the customer's expectations of the service provider regarding the provided activity, which include the quantity, quality, and cost-related expectations of the service,
- goals formulated by customer.

Having explored the literature and learned about the task to be solved, it can be stated that the solution must be approached and examined as a multi-criteria decision-making task. The steps of multi-criteria decision modelling can be found in the literature dealing with decision processes [6-8]. These consist of the following steps:

- delimitation of the decision-making task,
  - defining the general model from the point of view of service seekers,
  - to define a general model from the perspective of service providers (alternatives).
- solving the decision task.

To define a decision task, it is necessary to develop a general model and its mathematical scheme [9].

2.1 Definition of the general model

To determine the decision goal, it is necessary to know what objective functions can be used to describe the needs of a company looking for logistics services. The decision task means that we find the best service alternative for the user of the service using an optimization method based on the given objective functions. For management objectives, each applied objective function must be characterized by a specific set of parameters. When defining a general model, the first step is to record the elements that constitute the model. In this model, we considered two typical building elements: users of logistics services and logistics service providers.

Users of logistics services are interested in the logistics services available in the globalized market and their technical and economic parameters. The company that uses the service determines the objective functions, considering that it attempts to find the right service providers. These objective functions can differ according to a company's interests. Logistics service providers are characterized by the activities they provide and their technical, economic, and logistical aspects [10,11]. The logistics activity provided by the logistics service provider is characterized by various logistics parameters. Based on the above, we define the structure of the service seeker model as follows. In the first step, those looking for a logistics service are characterized by the objective functions they formulate for the service they are looking for.

Based on these results, the following conclusions can be drawn:

- the company looking for the *i*-th logistics service has special needs specific to the company,
- he searching company requires different logistics services, the maximum number of which is n_i, where *i* refers to the company searching for the *i*-th service,
- each requested logistics service is classified based on objective functions,
- different objective function numbers are typically used for each service, where $k_{i,j}$ represents the maximum number of objective functions for the *j*-th logistics service of the company seeking the *i*-th logistics service.

This proves that it is an extremely diverse general model that is complicated by additional factors to be considered. When managing the objective functions, it is essential to specify the parameters that characterize the given objective function. In general, it can be said that an objective function named C is characterized by a parameter with the number of P_c pieces. We select the *k*-th objective function for the *j*-th logistics service of the company seeking the *i*-th logistics service. Figure 1 illustrates the relationship between the service seeker, given service, given objective function, and parameters of the objective function.

The symbols in Figure 1 are as follows:

- *CF* - Objective function describing the given logistics service.
- *P* - Number of parameters characterizing the given objective function.

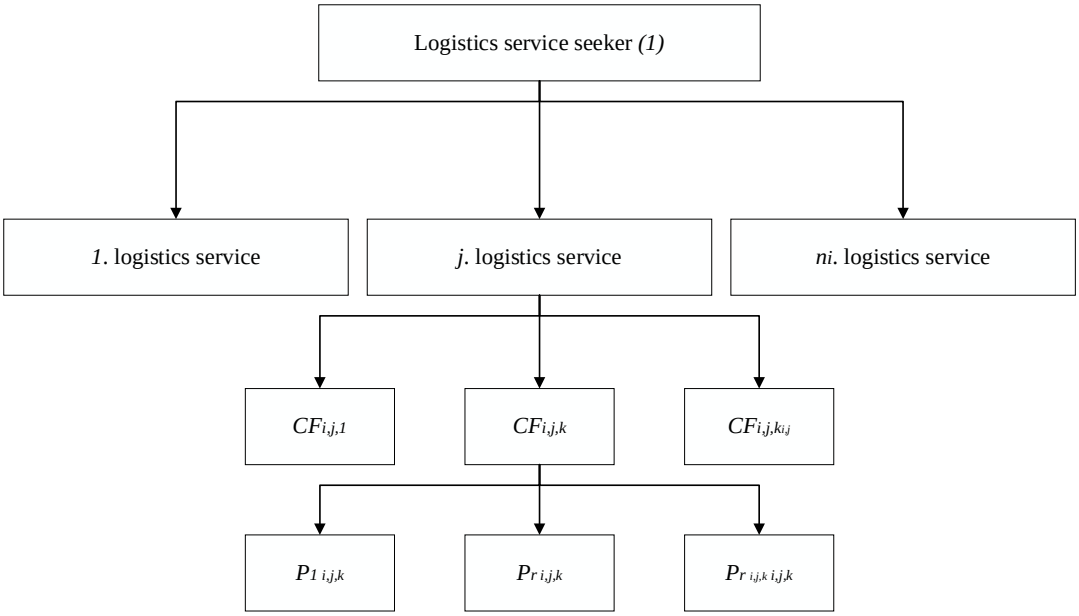

Figure 1 Characterization of companies looking for services

In the following, we supplement the model given in Figure 1 by specifying the maximum number of parameters as well as the connection system of the service finder, the service sought, and the maximum number of pieces of the given objective function. This is illustrated in the model shown in Figure 2.

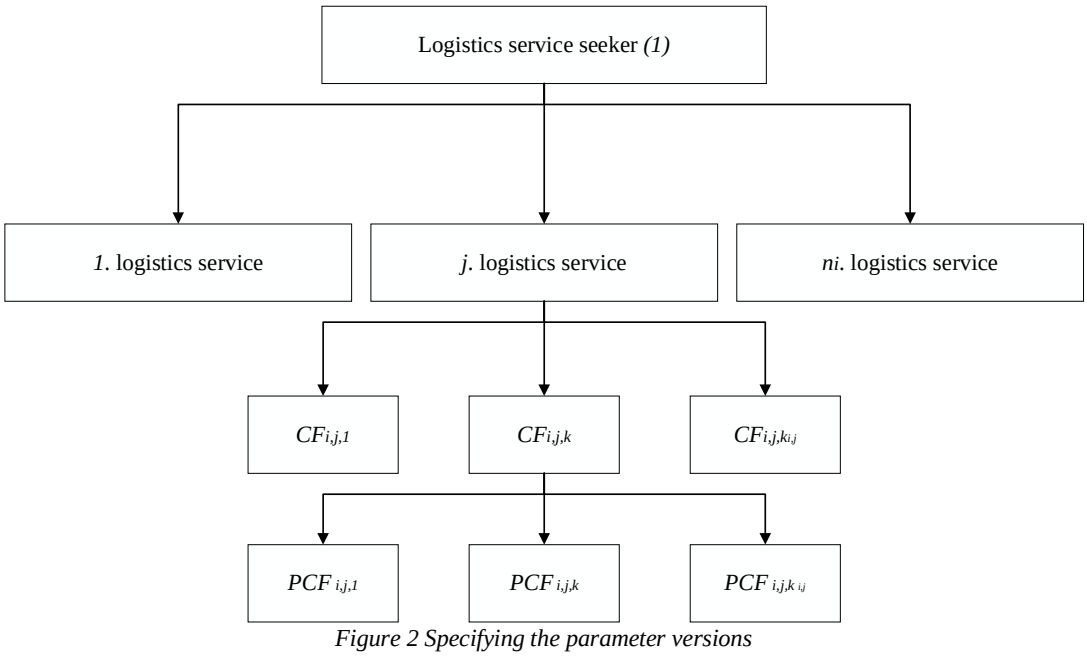

Figure 2 Specifying the parameter versions

In the Figure 2 the parameter versions of the objective functions are contained in the $PCF_{i,j,k}$ module, which is characterized by the following parameters:

- the *i*-th service seeker,
- for the *j*th requested service,
- in the case of the *k*th objective function,
- $r_{i,j,k}$ maximum number of parameters.

Using Figure 1 and 2, we provide the relationship system of companies looking for logistics services based

on the requesting company, the requested service, the objective functions for the service, and the parameters for the objective function. In the basic model, we took into account two building blocks: those looking for logistics services (consumers and buyers) and logistics service providers [12]. Previously, we defined those looking for logistics services, and now we define those who offer the service. In the following, we define the connection structure of logistics service providers, the service aspects they provide, and their parameters. During the investigation, a logistics service company was treated as a possible alternative solution. Logistics service providers can be classified according to various development levels (1Pl, 2Pl, 3Pl, 4Pl, 5Pl, etc.), these development levels represent the complexity of the offered service [13,14]. The range of services requested by the customer will determine the level of service companies that can be considered and involved in the evaluation [15]. Since several logistics service providers can be considered as solution alternatives in the competitive market, we consider m alternatives in the model. Each alternative has a different service aspect. These aspects and their specific numbers usually differ as alternatives. Figure 3 shows this.

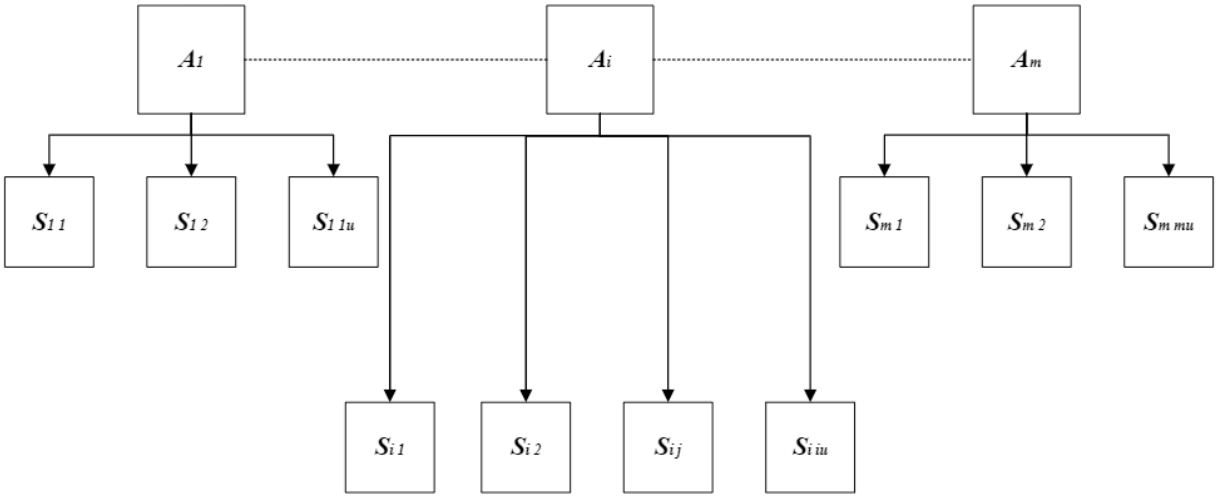

Figure 3 Offered alternatives and their aspects in relation to logistics service providers

The notations introduced in Figure 3 are as follows:

- A_i - the *i*-th service alternative, where $i=1,2,...m$.
- S_{ij} - the *j*-th service aspect of the i-th service alternative, where $j=1,2,\ldots u_{ij}$, and where u_{ij} is the last service aspect for the *i*-th alternative.

The connection system of the individual supply alternatives and the service aspects that characterize them (Figure 4) needs to be subjected to further investigations. Based on Figure 4, we cannot yet characterize the service aspects with sufficient accuracy, only the connection system is defined. For this reason, in the case of an *i*-th alternative, additional characteristics must be taken into account. This is illustrated in Figure 5.

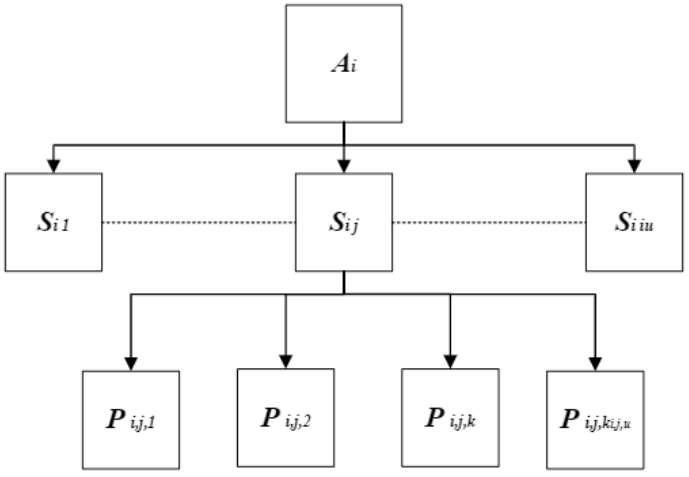

Figure 4 Offered service alternatives of i., the connection of parameter systems of $P_{i,j,k}$ defining the j. service aspect

The meaning of the notation used in Figure 5 is as follows: $P_{i,j,k}$ is the value of the kth parameter for the jth service aspect of the ith service alternative, where $k=1,2,\ldots k_{i,j,u}$ is the maximum number of parameters for the jth service aspect of the ith service alternative.

Using the results of Figure 3 and Figure 4, we can provide the supply side of our investigations, that is, the general model that can be used to characterize logistics service providers, the relationship system of the alternatives (service providers), the service aspects as our alternative and the characteristic parameters for all aspects of each alternative number and their associated values. Figure 5 describes this.

Based on the characteristics described above, the approach and principle course of the task takes place according to the following steps:

- defining the decision goal,
- exploring and recording the aspects necessary for the decision,
- defining the parameter system related to the decision criteria,
- exploring and characterizing the system of service providers (alternatives) that can be considered for the decision,
- statement of results.

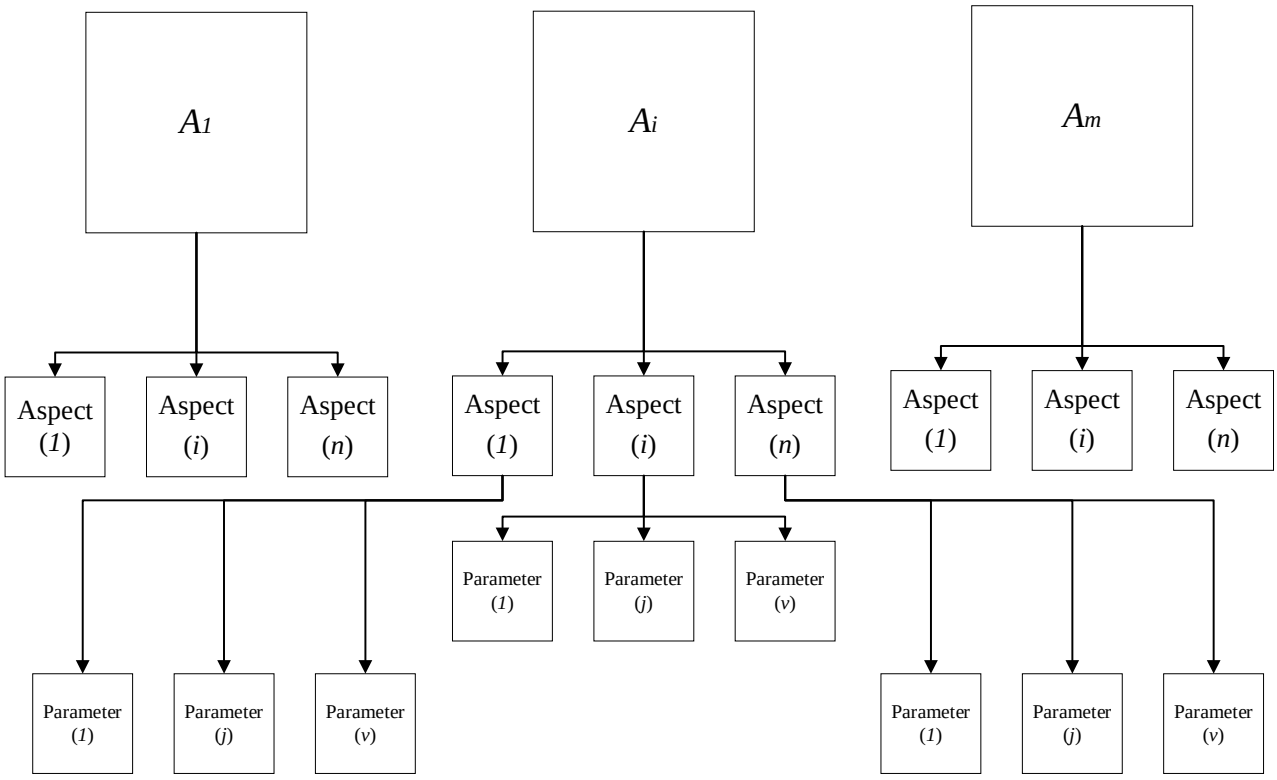

Figure 5 A general model for characterizing service providers

The outline of the solution to the decision task is as follows:

- evaluation of each possible service provider (alternative) based on all parameters of each aspect,
- defining the mathematical model of the evaluation,
- development and selection of the criteria-parameter weighting method required for evaluations,
- evaluation of the alternatives using the weighting factors for the parameters,
- using the multidimensional scaling method (MDS) to decide the number of dimensions and display the obtained values.

2.2 *Determination of decision goal, decision criteria and related parameter system*

Based on the above, it can be seen that several goals can be defined along a given objective function in order to find the result of the decision task. In our case, the goal that appears at the end of the task is the choice of the optimal logistics service provider for the user of the service based on given criteria. In practice, the tested parameters can be recorded taking into account the effective combination of price-value and quality [16,17]. The basic task is to develop a mathematical model or models suitable for solving the defined task by jointly applying the two proposed models (Figures 2 and 5).

In all cases, it is the task of the customer or consumer to define the criteria necessary for the decision. The term aspects are the collective name for a given set of

parameters. With regards to the predefined objective function, we can define the relevant aspects and assign the characteristic parameters to these aspects. Setting up the system of criteria is the task of the organization using the given service, which must strive to record the essential aspects and alternatives - this can also be done with the involvement of an expert. Experts are all persons who are involved in the consequences of decisions at some level. Decision theory distinguishes between individual and group decisions in terms of the number of decision makers.

In all cases, the creation of the related parameter system is necessary for the defined decision criteria [18]. The definition of the main evaluation criteria is task-specific since the goal to be achieved can always change along the given objective function. We can describe a given aspect with a set of parameters in order to achieve the desired result. A specific aspect may have a different number of parameters, depending on the weight of the given aspect compared to the others. Depending on this, it is possible to determine the number of characteristic parameters. The relationship between the aspects is shown in the following diagram with a tree structure (Figure 6).

2.3 Connection system of service providers (alternatives), aspects, parameters that can be used in the decision

By alternatives, we mean the service providers in question, from which the buyer or customer may be able to decide depending on the evaluation of the aspects and their associated parameters. The general model of the election is illustrated in the following Figures 6 and 7. For the model to be developed, we took as a starting point the relationships previously defined in Figures 1 and 2, which actually describe the objective functions defined by the companies looking for the service. Using these two Figures (Figures 1 and 2), we created Figure 6, which illustrates the relationship between service seekers (*SK*) and their related objective functions (*C*). On the other hand, it can be said that it is also necessary to develop a relational system that assigns different alternatives to individual objective functions. This is illustrated in Figure 7, on which we specifically examine the goal to be achieved along a single objective function, but as Figure 6 shows, this connection system must be examined for each objective function of the service finder. Regarding the objective functions, it can be said that an objective function is composed of several descriptive aspects, which can be further detailed with the parameters specific to each aspect. In this case, there are several possible alternatives (service-providing organizations), therefore, for each alternative, it is necessary to enter a specific value for each descriptive aspect and their parameters. This connection system is illustrated in Figure 7. Knowing the above, the goal is that the values included in the developed mathematical model provide us with the opportunity to optimally satisfy the given need based on various aspects. The goal is to create a matrix in which the elements offer a solution to the ideal solution of the given task during various mathematical procedures and by applying various optimization methods.

The developed model is characterized by the following:

- The goal to be achieved is defined.
- Related to the given goal, we record *i=1,2,...n* aspects that we will take into account.
- We define the number of descriptive parameters for all given *i=1,2….n aspects*. Of course, the number of parameters for each aspect can differ. In case of the first aspect the number of parameters is $P=1,2,\ldots v_1$; thus the marking of the parameters belonging to the first aspect is $P_{1,j}$ where 1 indicates the first aspect and *j* to parameter *j*. The first aspect's maximum number of parameters is v_1. This can be marked similarly for every parameter for every aspect. The number of parameters for aspect *i* is $P=1,2,\ldots\ldots v_i$; where v_i indicates the maximum number of parameters for aspect *i*. After defining the parameters for the final aspect we see that the number of parameters for aspect *n* (last) is $P=1,2,\ldots v_n$; meaning that the last aspect's maximum number of parameters is v_n. The different alternatives are connected to the goal defined aspect system's parameter system. The number of possible alternatives is $k=1,2,\ldots m$; so the number alternatives is *m*. $A_{i,j,k}$ marks the connection of a *j* parameter for an *i* aspect for a selected *k* alternative. These connections are visualized by Figure 7.
- Connection matrix *A*: *A[i,j,k], w*here
  - *i* is the running index of aspects in *i=1,2,….n* is where *n* is the number of maximum aspects,
  - *j* is the running index of parameters in $j=1,2,\ldots v_i$ where v_i is the *i=1,2,…n* aspects' maximum number of parameters,
  - *k* is the running index for alternatives in *k=1,2,…m* where *m* is the maximum number of alternatives.

Basically, three principles are applied when solving the process:

- Defining the decision problem,
- Comparative evaluation of the parameters,
- Synthesis of established results.

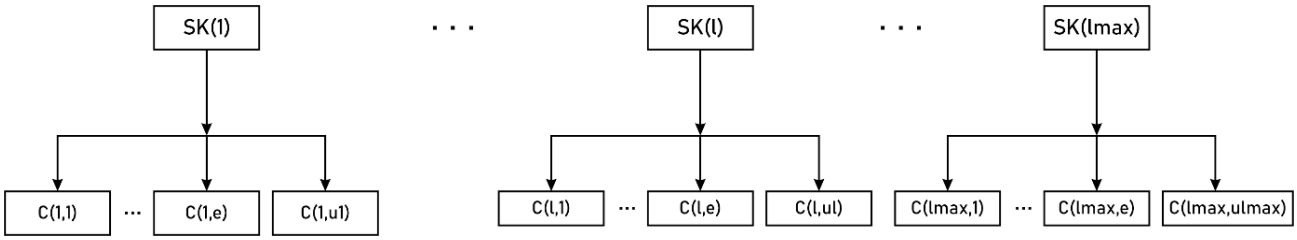

Figure 6 The systematic relationship of the objective functions defined by the service seekers

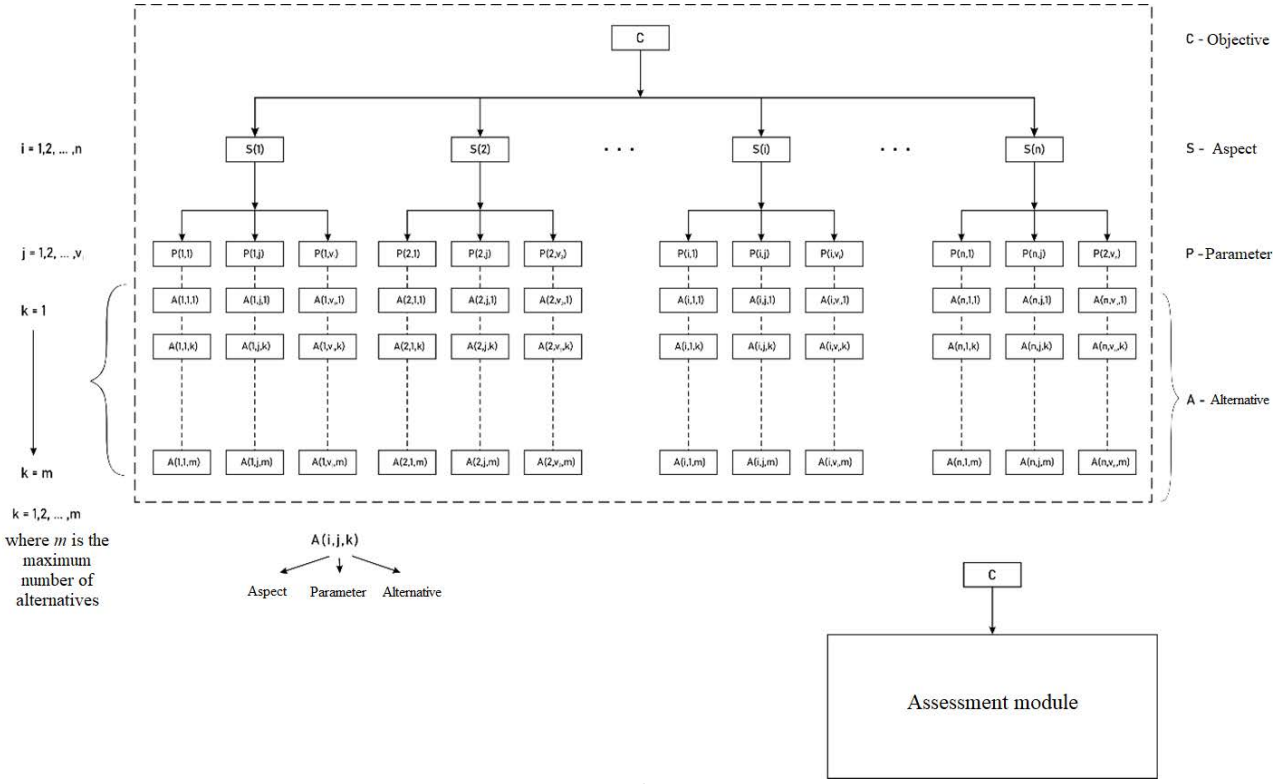

Figure 7 The relationship system of alternatives, parameters, aspects

2.3.1 The mathematical model of the evaluation

It is the responsibility and competence of the service user to define the best suiting target diagram with which it can start the examination. A goal supporting aspects system must be defined according to which the selection task can be successfully executed. The defined aspects must be evaluated with specific parameters with the use of input data and background databases. Input data means the priority defined by the company and the differences in priority between aspects. Databases can provide the data on previous evaluation results, different statistical reports, and information in the form of questionnaires. The used database must confirm to the buyer's goal's and to the characteristics of the aspects and aspect defining parameters. The established data structure and the primary connection system of the evaluated data can be introduced with the $a_{i,j,k}$ matrix where the components of the matrix are:

- the aspects to be considered according to the goal ($i=1,2,\ldots n$),
- all evaluated aspect can be defined by the determined parameters and their given values,
  - the number of needed defining parameters are usually different for each aspect ($j=1,2,\ldots v_i$),
  - used parameters usually have different dimensions,
- the evaluated alternatives generally give different solutions and values for a given aspect's parameter.

The datasets created this way show the solution offered by a given goal's *i* aspect's *j* parameter's *k* alternative. The evaluated dataset gives us basis for the following optimal tasks:

- defining the optimal alternative for reaching a defined goal using the matrix's data,
- defining the improvement methods of solution parameters provided by a given alternative with the use of digitalization methods and according to market aspects (costs, quality improvement of parameters, improvement of market competitive position).

Taking the following parameter set into consideration and with the use of the developed model we will demonstrate the method of finding the optimal. In the first step of the evaluation we will define the $a_{i,j,k}$ three dimensional matrix. Starting form the A =[$a_{i,j,k}$] matrix, we define the *i*th aspect's *j*th parameter's *k*th alternative, which has the value of $a_{i,j,k}$. The result will be defined by the evaluated alternative. According to the evaluated parameter's properties this can be a maximizing of minimizing value. If the parameter is maximizing (1) then we search for the maximum of the $a_{i,j,k}$ based on the alternative's (*k*) parameter (*j*) where the appropriate objective function is:

$$P_{max\,i,j,k} = \max_i\{a_{i,j,k}\} \tag{1}$$

In the next step we define the relative value (2) of the $a_{i,j,k}$ according to the following:

$$P_{i,j,k} = \frac{a_{i,j,k}}{P_{max\,i,j,k}} \tag{2}$$

where

$$0 \le P_{i,j,k} \le 1 \tag{3}$$

In case the parameter is minimizing (4) then we search for the minimum of the $a_{i,j,k}$ based on the alternative's (*k*) parameter (*j*) where the appropriate objective function is:

$$P_{min\,i,j,k} = \min_i\{a_{i,j,k}\} \tag{4}$$

In the next step we define the relative value (5) of the $a_{i,j,k}$ according to the following:

$$P'_{i,j,k} = \frac{P_{min\,i,j,k}}{a_{i,j,k}} \tag{5}$$

where

$$1 \le P'_{i,j,k} < \infty \tag{6}$$

For the proper handling of $P'_{i,j,k}$ we define $P_{i,j,k}$ which provides the use of relative parameters (there is no ∞ value). $P_{i,j,k} = \frac{1}{P'_{i,j,k}}$ in this case $0 < P_{i,j,k} \le 1$ then we get the *j*th value of the *i*th aspect's relative *k*th alternative ($P_{i,j,k}$) where *i=1,2,…n.* If we perform this for all parameters of a given *k*th alternative, we get the relative parameter matrix for the that *k* alternative. This step must be repeated for all k=1,2,….m alternative to get m number of similarly built matrixes. This three dimensional matrix P = [$p_{i,j,k}$] will be the base for the execution of possible optimal methods.

2.3.2 The method of weighting

The first possible solution finding method is the weighting of evaluated parameters. Because of this it is essential to properly define the aspect's/indicator's weighting scale for the effectiveness of the model. In reality, when searching for a solution (alternative) each parameter has different importance for the buyer. We can validate the differences in importance by introducing weighting formulas (7). In the case of the kth alternative's *i*th aspect's *j*th parameter, the weighting formula's value is $w_{i,j,k}$; where

$$0 < w_{i,j,k} < 1 \tag{7}$$

assuming that $j=1,2,\ldots v_i$.

In regard to the weighting formulas (7), it is a given that

$$\sum_{j=1}^{v_i} w_{i,j,k} = 1 \tag{8}$$

where i and k are constant.

When defining the $w_{i,j,k}$ values we must take the above written into account. In these correlations $j=1,2,\ldots v_i$ must always be fulfilled for all values of $i=1,2,\ldots n$ and $k=1,2,\ldots m$. Based on these we can define the W = [$w_{i,j,k}$] matrix, which contains the weighting formulas value.

We evaluate the appropriateness of the *k*th alternative (9). The *k*th alternative's *i*th aspect's evaluation indicator is the following:

$$e_{i,k} = \sum_{j=\overline{1}}^{v_i} w_{i,j,k} \tag{9}$$

where i and k are constant.

This $e_{i,k}$ evaluation indicator gives how appropriate the *k*th alternative is for the *i*th aspect. If we perform the above summarization for a given alternative's every evaluation aspect (9) then we get the *k*th alternative's result indicator (10). The result indicator for the *k*th alternative is the following:

$$e_k = \sum_{i=1}^{n} e_{i,k} \tag{10}$$

through this we get the result indicator for the kth alternative. Since the maximum number of alternatives is *m*, we must define the result indicator for every *k=1,2,…m* alternative. Afterwards, according to correlation (10) we get the e_{opt} (11) and the

$$e_{opt} = \max_k\{e_k\} \tag{11}$$

which gives e_{opt} and the ralting $k=k_{opt}$ value.

2.3.3 Application of the multidimensional scaling (MDS) method

The literature on multidimensional scaling (MDS) is now quite extensive, well known, and often uses statistical procedures. With its help, the 2- or 3-dimensional representation of multi-dimensional objects becomes possible, where, based on the resulting Figure, hidden relationships may exist between the evaluation and certain properties of the categories. Thus, the magnitude relationships of the distances between the points of the original set of points are also preserved. The essence of the

procedure is that we are given n objects, of which p properties are observed one by one, from which we can create an n×p data matrix, in which the n rows of the matrix represent the objects (points) and the p columns represent the observations given to the points. Our goal is to embed objects in Euclidean space. If two of our elements are far from each other in a certain sense in our original p-dimensional space, then we want them to be far from each other in this k-dimensional Euclidean space, that is, our elements are equally far from each other in the reduced space, within a certain margin of error.

Examining the literature, the method is mainly used in the field of sociology, where properties have to be scored on a specific scale; however, in our case, it can also be used effectively as a decision support method for selecting a logistics service provider. The MDS method can be used as a part of the general model presented above and the mathematical procedures of the evaluation process. The justification for using this method was the fact that in today's digital environment, many service providers offer themselves as potential options on the competitive market, the number of evaluation criteria and descriptive parameters is increasing, and the handling of the resulting datasets is becoming increasingly complicated. Using this method, it is possible to reduce a large number of criteria such that it provides an exact easy-to-understand solution for the person responsible for the decision [19].

Various statistical software packages are available for the application of the MDS method. In our case, we used the Statistical Product and Service Solutions (SPSS) software developed by IBM. In the case of the initial configuration in the procedure, there are usually no distance matrices available but raw data. This usually means that we have information about each object and evaluate it along some dimensions. The distance matrix should then be obtained from this information [20].

3 Example

In this section, the practical use of the previously presented procedure is introduced. In this example, aspects and their descriptive parameters were defined. The numerical values were also the result of random assignments (Table 1).

Table 1 Service provider evaluation board

	Name of aspects/parameters	Weight factor	Value (1-100)									
			A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	A_{10}
S_i	**Delivery**	0.2										
Sz_1	By on-time delivery	0.08	55	53	97	25	60	52	42	33	71	21
Sz_2	Accounting and invoicing accuracy	0.04	76	8	72	55	37	19	42	54	32	24
Sz_3	Condition of vehicles	0.05	10	35	75	42	35	43	42	62	43	98
Sz_4	Loading and unloading	0.03	77	75	7	16	17	13	42	58	81	93
R_i	**Storage and inventory**	0.15										
R_1	The characteristics of the order process	0.01	93	70	65	16	43	67	85	6	48	32
R_2	Accuracy of order fulfillment	0.06	70	65	16	43	67	85	8	48	32	76
R_3	On-time storage	0.03	69	95	30	78	51	39	60	26	25	4
R_4	On-time pick-up	0.03	63	75	61	59	40	90	86	26	67	75
R_5	Appropriate regulation of stocking	0.02	43	10	33	16	30	60	87	59	23	40
M_i	**Service level and quality**	0.25										
M_1	Availability of tools and resources	0.08	81	85	62	84	55	91	36	45	27	48
M_2	Problem-solving ability	0.06	55	37	44	11	56	24	8	40	10	38
M_3	Quality of the transport and warehousing service	0.07	97	83	62	39	66	18	4	8	47	69
M_4	Financial stability of the company	0.02	15	72	59	16	19	23	43	40	44	90
M_5	Market reputation	0.01	91	19	66	53	36	38	59	92	88	75
M_6	Ability to operate on a global scale	0.01	13	84	28	55	34	35	83	83	50	87
K_i	**Costs**	0.3										
K_1	The (specific) cost per transport unit	0.005	6	68	12	63	21	46	30	19	45	36
K_2	Storage cost per storage unit	0.005	13	9	64	12	28	66	76	81	9	52
K_3	Service cost	0.02	61	57	82	79	96	37	73	69	77	43
T_i	**Applied technique and technology**	0.1										
T_1	Application of tracking systems	0.05	32	17	47	44	20	64	23	48	57	7
T_2	Provision of electronic data exchange (EDI)	0.01	23	48	57	7	41	46	99	20	71	26
T_3	Provision of Internet and e-commerce	0.02	55	80	63	50	40	22	37	23	70	60
T_4	Willingness for process improvement	0.01	44	33	67	87	85	22	63	71	18	29
T_5	Willingness to develop technology	0.01	33	21	10	67	43	95	65	39	79	81

After the weighting is done, the table takes the following values, as shown in Table 2.

Table 2 Weighted indicators of the evaluation of the service provider

	Name of aspects/parameters	Weighted value									
		A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	A_{10}
S_i	**Delivery**	10.25	8.56	14.60	6.78	8.54	7.46	8.40	9.64	11.54	10.33
R_i	**Storage and inventory**	9.95	9.9	5	7.17	7.78	10.84	7.45	5.68	5.62	8.05
M_i	**Service level and quality**	17.91	17.3	14.06	11.51	13.46	11.17	5.92	9.11	8.31	14.37
K_i	**Costs**	1.315	1.525	2.02	1.955	2.165	1.3	1.99	1.88	1.81	1.3
T_i	**Applied technique & technology**	3.7	3.47	4.95	4.81	3.49	5.27	4.16	4.16	5.93	2.91
		43.13	40.76	40.63	32.23	35.44	36.04	27.92	30.47	33.21	36.96

The color marking illustrates the obtained result, the service providers marked in green performed the best and those marked in red performed the worst. The next step is the multidimensional scaling procedure (MDS), which we use in the example using the SPSS software. In the first step, with the help of the program, we create a distance matrix from the received weight values of the aspect (Table 3), which illustrates the Euclidean distance of the points measured from each other in the 5-dimensional space (Table 4).

Table 3 Criteria weight values received as a service provider

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
Delivery	10.25	8.56	14.60	6.78	8.54	7.46	8.40	9.64	11.54	10.33
Storage and inventory	9.95	9.9	5	7.17	7.78	10.84	7.45	5.68	5.62	8.05
Service level and quality	17.91	17.3	14.06	11.51	13.46	11.17	5.92	9.11	8.31	14.37
Costs	1.315	1.525	2.02	1.955	2.165	1.3	1.99	1.88	1.81	1.3
Appl. technique and technology	3.7	3.47	4.95	4.81	3.49	5.27	4.16	4.16	5.93	2.91

Table 4 The measured distance of the dimensions included in the study

	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	A_{10}
A_1	0.000									
A_2	1.824	0.000								
A_3	7.766	8.569	0.000							
A_4	7.898	6.792	8.508	0.000						
A_5	5.311	4.433	6.853	3.010	0.000					
A_6	7.515	6.554	9.698	3.832	4.437	0.000				
A_7	12.414	11.672	10.551	5.863	7.580	6.453	0.000			
A_8	9.827	9.309	7.086	4.073	5.007	6.098	3.855	0.000		
A_9	10.853	10.684	6.619	6.048	6.802	7.264	4.700	2.719	0.000	
A_{10}	4.095	3.938	5.684	5.059	2.278	5.642	8.805	5.972	7.313	0.000

The mathematical quality of the MDS procedure in SPSS is characterized by the following two fit indicators, s-stress and RSQ. The s-stress indicator is nothing but an indicator calculated from the difference between the coordinates of the plotted and the original points. Therefore, the smallest values of s-stress are desirable, because they correspond to the smallest possible distortion (Table 5).

Table 5 The value and quality of the S-stress indicator (based on my own editing [9])

S-Stress	Quality	Comment
<0.05	Excellent	It probably contains all the relevant information.
0.05<0.1	Good	Correct, the results are interpretable.
0.1<0.15	Medium	The results stand their ground in relation to the task.
0.15<0.2	Acceptable	It's worth dealing with. The result is still mostly interpretable.
0.2<	Inadequate	For the given dimension number, it can only be represented with a large loss of information. It is worth using a larger dimension number.

RSQ (R SQUARED) - another fit indicator calculated by SPSS - is simply the square of the correlation coefficient calculated between the corresponding elements of the plotted and the original matrices, which directly indicates what proportion of the total variance can be explained by the given MDS model [21]. For this indicator - in contrast to the previous one - of course, lower values indicate a

worse fit. *RSQ> 0.6* is the acceptable value range. In the example, with regard to the given data set:

- Stress = 0,06053 → Takes a "good" value.
- RSQ = 0,98481→ Appropriate value.

The next step of running the program is to determine the coordinates of the points in the space transformed to 2 dimensions (Table 6).

Table 6 Coordinates of points in 2D space

	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	A_{10}
Dim1	1,8428	1,6511	0,2819	-0,3506	0,3707	-0,1066	-1,8942	-1,1131	-1,3914	0,7094
Dim2	-0,053	0,383	-1,7974	0,7314	0,2296	1,1807	0,5191	-0,2404	-0,7195	-0,2333

The next step is to determine the distance of the points located on the transformed projection. In the last step, the dot plot reduced to two-dimensional space is shown. This mapping means mapping the five-dimensional (point of view) space into two dimensions, where in fact all 5 original dimensions appear to a greater or lesser extent. From the point diagram and the standard deviation of the alternatives, we can deduce where the original dimensions appear in the new coordinate system. Deciphering the *X*-axis was quite clear, since the points are scattered mostly along the service level dimension (Table 7).

Table 7 The distribution of the standard deviation of each descriptive aspect

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	*Deviation*
Delivery	10.25	8.56	14.60	6.78	8.54	7.46	8.40	9.64	11.54	10.33	***2.14***
Storage and inventory	9.95	9.9	5	7.17	7.78	10.84	7.45	5.68	5.62	8.05	***1.90***
Service level and quality	17.91	17.3	14.06	11.51	13.46	11.17	5.92	9.11	8.31	14.37	***3.66***
Costs	1.315	1.525	2.02	1.955	2.165	1.3	1.99	1.88	1.81	1.3	***0.32***
Appl. technique and technol.	3.7	3.47	4.95	4.81	3.49	5.27	4.16	4.16	5.93	2.91	***0.89***

Regardless, the other dimensions also make their impact felt in the reduced space, for example two original dimensions are close to the *y* axis: transportation and storage and inventory. The reason for this is that these original dimensions also correlate (negatively) with each other (Table 8).

Table 8 The magnitude and direction of the linear relationship between the two aspects

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	Correlation
Delivery	10.25	8.56	14.60	6.78	8.54	7.46	8.40	9.64	11.54	10.33	-0.5715
Storage and inventory	9.95	9.9	5	7.17	7.78	10.84	7.45	5.68	5.62	8.05	

Among the original dimensions, the 4th (applied technique, technology) and 5th (costs) dimensions are also included in the reduced space, but their position is more difficult to determine, as they are less differentiated in the initial five-dimensional space. After the investigation, as a result of the conclusion, it can be concluded that the best correlating aspect during the transformation is the level of service and quality (M_i) displayed on the horizontal (x) axis, the next two best correlating aspects along the vertical (y) axis are transportation and storage and inventory. The axes depicted in the diagram are oriented according to the display shown in Figure 8. Along the x-axis, the neighborhood of the minus value can be interpreted as the "lower" service level, and in the direction of the positive value, the "higher" service quality can be seen. Along the y-axis, the minus value is represented by service providers focusing on the "delivery aspect", and the positively oriented value is represented by the service providers focusing on the "warehousing and stocking" aspect.

The essence of the technique used lies in the fact that we can display the service providers qualified in the complex evaluation system in a two- or three-dimensional coordinate system where the axes represent various properties and the service providers are scattered along these trends. This makes it clear to the decision-makers what the individual service providers are stronger than their competitors, as well as what the strengths and weaknesses of the individual service providers are and which is the best service provider in the comparison.

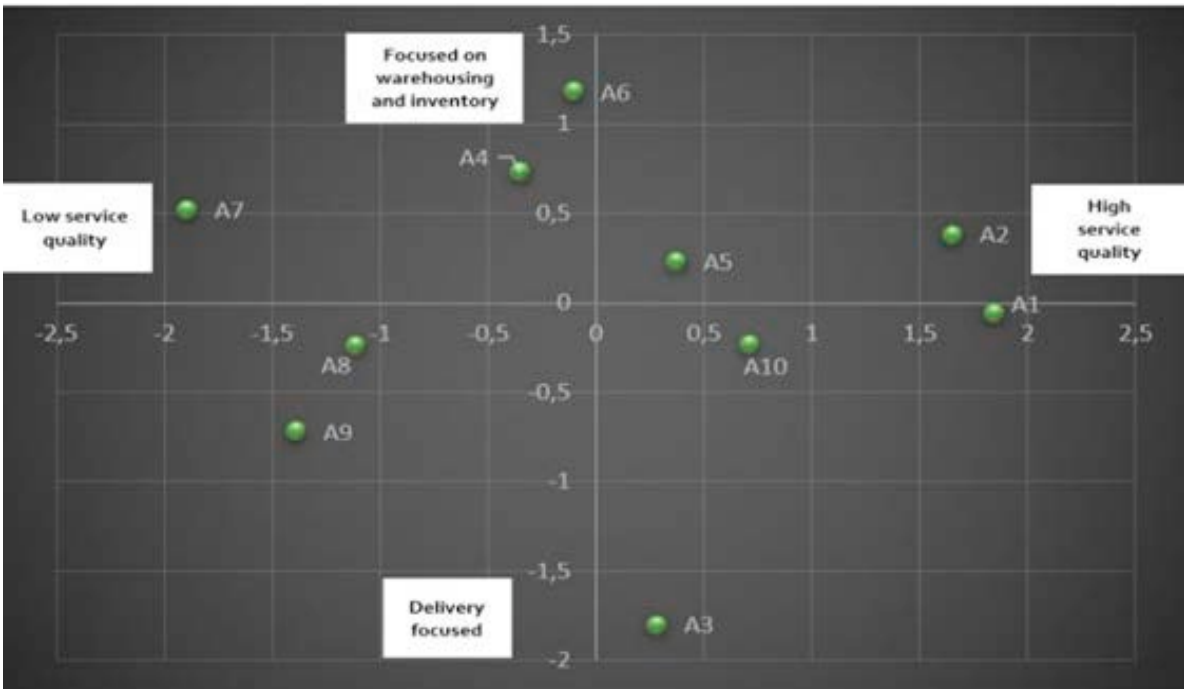

Figure 8 Scattering of alternatives in the transformed dimensional space

4 Conclusion

The choice of the topic of the article was justified by our experience gained in company practice, as well as the possibilities inherent in the complexity of the evaluation and selection process. The selection of logistics service providers is a complex process that requires careful consideration of numerous factors [22]. By examining cost factors, service quality and reliability, operational capabilities, geographical coverage, and technological advancements, organizations can make informed decisions that align with their unique supply chain requirements [23]. Ultimately, selecting the right LSP can lead to enhanced operational efficiency, improved customer satisfaction, and increased competitive edge in the marketplace. In this study, research directions related to more efficient operation applicable to the evaluation and selection of service providers were formulated. We explore today's service offerings of the logistics sector, present their portfolios in detail, and outline the multi-level evaluation-preference indicators illustrating the overall evaluation of these service providers. The presented results give practice the opportunity to evaluate the service provider providing added value primarily from the perspective of the service user, i.e. the buyer/consumer. The test method was specifically presented as a decision support method for the evaluation process of companies providing logistics services; however, with minimal correction, it can be used for all evaluation-selection processes. The achieved selection ranking can also be considered a benchmark evaluation for the service provider, with which it can position itself in a competitive market. In relation to the task, the limitations indicate how relevant the aspects describing the objective function and the parameters characterizing the aspects are to the objective function. Therefore, in practice, it is necessary to involve experts with sufficient competence to determine the necessary aspects for this task. These experts can also be internal employees of the company or, if necessary, external specialists specializing in this task Several additional development possibilities can be mentioned, among them the extension of the test model by the service provider to the evaluation of the consumer, as well as the development of a computer web application suitable for the application of the testing methods at the company level be highlighted.

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Sustainable logistics and passenger transport in smart cities
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Sustainable logistics and passenger transport in smart cities

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Keywords: sustainable development, smart city, sustainable logistics, green logistics, ecology, e-commerce.
Abstract: The rapid growth of urban populations, coupled with the imperatives of decarbonization and the relentless march of urbanization, has thrust modern cities into a crucible of multifaceted challenges. In response, the Smart City concept has emerged as a shared paradigm for addressing these urban complexities. This transformative approach touches upon various facets of urban life, encompassing areas such as the economy, education, and governance. Among these, logistics stands out as a pivotal component of the Smart City framework, necessitating innovative and sustainable solutions. This article delves into the intricate nexus between sustainable logistics systems and the evolution of the Smart City concept. Drawing from both qualitative and quantitative research methodologies, including multivariate analysis, the study synthesizes data from primary sources collected during a series of European projects conducted from 2020 to 2023, in addition to secondary data sources. A central inquiry revolves around the symbiotic relationship between e-commerce dynamics and the sustainability of smart city logistics solutions. The findings of this investigation illuminate a compelling correlation between the profitability of logistics enterprises and the key indicators of logistics development underpinning smart cities. By unveiling these interdependencies, this research contributes to our understanding of how sustainable logistics and passenger transport systems are pivotal to the ongoing development of smart cities, offering valuable insights for urban planners, policymakers, and industry stakeholders alike.

1 Introduction

An ever-increasing share of the world's population lives in cities, which creates new and deepens existing problems regarding the disposal of more significant waste amounts, aggravating the problems of traffic jams and environmental pollution. These processes are accompanied by reducing resources necessary for life, [1], and force to pay more and more attention to "green" issues in development decision-making, [2].

Experts in ecology, politics, and economics have concluded that the Smart City concept is a response to the growing number of problems, [3]. The city into a “smart” one is transformed by implementing innovations, regardless of the master plans of such cities, [4]. A smart city is defined not by an urban plan but by the ability to adapt to the demands arising in the course of economic, technological, and cultural development, [5].

The Smart City concept applies to changes in the economy, education, management, mobility, the environment, and the lives of residents, [6]. Mobility is a critically important area — transport, passenger and cargo transportation, and logistics in general. Urban development decisions inevitably adapt to the necessary logistics solutions, [7].

The field of logistics serves all other areas of life, has a significant positive impact on solving the problems of modern cities, [8-10], and is a source of different problems, including harmful emissions, traffic jams, noise pollution, accidents, [11-13]. Meanwhile, scholars coined the concept of green logistics, focusing more on the environmental impact of logistics and the concept of sustainable logistics,

comprising environmental issues of logistics and social and economic aspects of logistics, [14,15]. Both concepts play a vital role in the context of the Smart City concept, [16].

The vector of sustainable logistics aims to ensure environmental friendliness and a socially and economically prospering orientation of supplies and transportation, [17]. Hence, sustainable logistics must ensure the needs of customers in quality goods and convenient methods of delivery and transportation with minimal damage to the environment, [18], realized through green transport technologies with low emissions and circular economy-oriented approaches in packaging and storing of goods by using information and communication technologies (ICT) and the introduction of the Smart Logistics concepts, [19]. The sustainable logistics system's development goes alongside the evolution of related fields comprising new ICT developments, abatement and automatization technologies, green energy concepts, circular economy implementations and e-commerce.

The study aims to determine the mutual influence of the logistics system development as a basis for the development of a smart city and related areas. The aim involved the fulfillment of the following research objectives:

- Outline the conceptual framework of the study.
- Assess the infrastructure and logistics of European countries and establish a link between the efficiency of logistics and related areas.
- Assess the influence of e-commerce development indicators on the profit of international logistics companies.

The research used the following methods: system-structural approach, cluster approach, correlation analysis, and economic and statistical analysis. The conceptual framework was built for the conducted research, which made it possible to describe the relationship between sustainable development, smart city, and sustainable logistics concepts. Correlation analysis was used to determine that the development of e-commerce is closely related to the development of logistics and infrastructure in European countries. It was determined that there is also a close correlation between the profit of some of the studied logistics companies and logistics development indicators. Future research should focus on identifying differences in the transformation of the logistics system based on sustainable development in the B2B, B2C and B2G sectors.

2 Literature review

The research is based on a clear understanding of the Smart City concept and current trends in logistics and passenger transportation within the Sustainable Logistics concept. The research problem is reflected in the work of authors, [20], which provides predictive results regarding the trend toward an increasing population living in cities. Therefore, cities will have to provide many residents with sufficient resources while issues of ensuring economic, ecological, and social sustainability come to the fore. The researchers note that transforming the city into a Smart City requires solving several urgent problems, which necessitates close cooperation between the state and private participants.

The study's theoretical framework is based on the work of authors, [21], who distinguish areas related to the Smart City concept. In addition to the smart economy and providing jobs, a smart industry should be developed in a smart city, primarily related to ICT development. Moreover, the process of transforming the city into a Smart City should take into account modern transport technologies. In creating a list of aspects that should be improved in smart cities using ICT, researchers, [22], put smart mobility first.

Many researchers focus on ecological (green) and sustainable logistics issues. In work, [23], note that growing attention to the problems of mitigating the adverse effects of transport and increasing the productivity of supply chains. Researchers, [24], dwell on the analysis of existing definitions of sustainable logistics and conclude that most studies focus on ways to reduce the negative impact of logistics operations on the environment. Authors, [25], investigate energy efficiency and greenhouse gas emissions in logistics hubs.

In work, [26], deal with the issues of sustainable logistics in smart cities, formulating the primary goal of logistics management of a smart city — sustainable development through reducing the consumption of natural resources and optimizing the provision of services. This study (on the example of Brazil), as well as authors, [27], (2020) (China) and researchers, [28], (Australia), assigned a key role in the evolution of smart cities to urban logistics. Authors, [4], characterize urban logistics as an imperative mechanism of a smart city. Using the example of Smart City projects in the United States of America (USA) and the EU, Paskannaya and Shaban, [29], conclude that the goal of implementing such projects is to minimize damage to the environment, increase the efficiency of the use of material and technical resources and the process of making management decisions.

Another relevant direction is the study of the connection between the development of logistics and the e-commerce market. In turn, electronic commerce has a significant connection with the development of ICT, [30], which is the basis for the evolution of smart cities. In work, [31], note that the rapid growth of e-commerce creates new opportunities for global growth in the number of logistics service providers. Hoffmann and Prause, [32,33], point out the sustainability gains of autonomous delivery robots in e-commerce and tele-driving concepts in urban personnel transportation by highlighting the importance of the last-mile problem for logistics.

3 Methods and materials

The structure of the article consists of three consecutive stages. The first stage provided for defining a conceptual research framework using the system-structural approach that considers the concepts of sustainable development and

its goals, Smart City and logistics, the combination of which produces the definition of sustainable logistics.

The second stage involved a choice of a region for further analysis - the countries of Europe. The region was chosen by the location of most of the world's developed smart cities and the implementation of efficient logistics systems. The list of countries for analysis was determined - 37 European countries with the data on infrastructure and logistics freely available in the European E-commerce Report 2022, [34]. This Report provides information on rankings and indices regarding the infrastructure of European countries, so the results of using the ranking method were applied in the research. The following indices were used in the study: Logistics Performance Index (2018), Ease of Doing Business Index (2020), E-Government Development Index (2020), Inclusive Internet Index (2021), Universal Postal Union Reliability Score (2021), UNCTAD B2C E-commerce Index Ranking (2020), Environmental Performance Index Ranking (2020), Global Cybersecurity Index Ranking (2020).

The data of the European E-Commerce Report 2022 contributed to the research questions' solution by applying multivariate analysis methods. The focus of the methods was laid on hierarchical cluster analysis by using Ward's minimum variance method with Euclidian distance and correlation analysis by interpreting the values of the country vectors of the European E-Commerce Report 2022 as metric scaled. In addition to the European E-Commerce Report 2022 data set, other metric-scaled data from secondary sources complemented the study.

The cluster analysis was used to divide 37 European countries into three clusters according to the indices mentioned in the previous paragraph because this number of clusters was optimal through the analysis of average graphs.

The correlation analysis was conducted for the Logistics Efficiency Index and other above-mentioned indices. It was determined which indices are most closely related to the Logistics Performance Index and, therefore, hypothetically influence the trends in the logistics industry. According to this analysis, the development of logistics in the world is most closely related to the development of electronic government, electronic commerce, and environmental indicators. The study of the relationship between the development of logistics and e-commerce indicators represents the highest interest among these indicators, which can be justified as follows:

- The first, there is a close correlation between the Logistics Performance Index and the UNCTAD B2C E-commerce Index.
- The second, the analysis of academic literature shows a high interest of researchers in the trends of logistics and e-commerce, and many studies note the mutual influence of these spheres.
- The third, e-commerce is one of the key current trends, as well as the development of the digital sphere in general, so logistics companies cannot fail to consider this influence in their activities. This influence extends not only to changes in user requirements but also to the need to introduce the latest technologies in logistics companies — for example, providing the ability to book/buy tickets for passenger transportation online, compare routes, choose alternative carriers, vehicles, travel time and others.

The third stage of the research provided for determining the dynamics of net profit and net income of logistics companies engaged in passenger transportation (GAL-VSESVIT LLC, East-European Travel Joint Ukrainian-English Company, GUNSEL LLC) using economic and statistical analysis. Ukraine is of high scientific interest in the context of the study, as the aspects of the post-war recovery of the country head the list of the most critical tasks for the Ukrainian government and international partners, given a large-scale invasion of the country and the urgent issue of granting Ukraine the EU member status. The post-war recovery could be most effective using Smart Cities and Sustainable Logistics concepts.

Table 1 Indicators of net profit, net income of companies and e-commerce development indicators for correlation analysis

UAH thousand	2019	2020	2021	2022
GAL-VSESVIT LLC (net income)	82,546.00	37,437	60,838	128,925
GAL-VSESVIT LLC (net profit)	-10,697	-11,037	1,276	16,715
East-European Travel Joint Ukrainian-English Company (net income)	26,852.7	12,443.4	17,468.4	20,042
East-European Travel Joint Ukrainian-English Company (net profit)	1,763.4	1,028.2	799.8	450.8
GUNSEL LLC (net income)	172,585.1	148,111.7	217,974.5	49,306.6
GUNSEL LLC (net profit)	-1,4165	-6,177	6,176.1	-9,176.2
Online buyers in Europe (% of total internet users)	69	74	73	75
Online buyers in Ukraine (% of the total number of Internet users)	35	40	44	48
The volume of the e-commerce market in Ukraine (USD milliard)	2.9	4.0	4.4	5.1
The share of e-commerce in Ukraine (% of the volume of retail trade)	6.9	8.8	9.2	9.7
Dynamics of global volumes of electronic retail sales (USD milliard)	3,535	4,206	4,927	5,695

Source: compiled by the authors according to [35].

The correlation analysis was also used to establish a connection between the net profit and net income of the above-mentioned companies on the one hand and the e-commerce indicators on the other. Hypothetically, companies' net profit, as the main result of their activity, should reflect the current trends in the economy and the degree of their influence on the company's activities. Determining the correlation between net profit, company income, and e-commerce indicators is an important task considering that the development of e-commerce and the

scope of application of its tools by the company is one of the leading such trends and probably affects the activities of logistics companies. In other words, an attempt was made at this stage to identify close correlations between the net profit and net income of companies, on the one hand, and the following indicators of the development of e-commerce, on the other:

- The percentage of online buyers in Europe, the percentage of online buyers in Ukraine.
- The volume of the e-commerce market of commerce in Ukraine, the share of e-commerce in Ukraine.
- The dynamics of global volumes of electronic retail sales.

As a result, a rectangular correlation matrix was built with the determination of the strength of the correlation. Table 1 shows the indicators of net profit, net income of companies and e-commerce development indicators for analysis, all representing metric scaled values.

4 Results

4.1 Conceptual framework of the research

The Sustainable Development, Smart Cities, and Sustainable Logistics concepts are closely related and interdependent (Figure 1). The evolution of smart cities is inextricably linked with such Sustainable Development Goals (SDGs) as sustainable development of cities and communities, decent work and economic growth, quality education, industry, innovation and infrastructure. Sustainable logistics is a necessary prerequisite for developing a smart city and, in turn, concerns such SDGs as responsible consumption and production and mitigation of climate change.

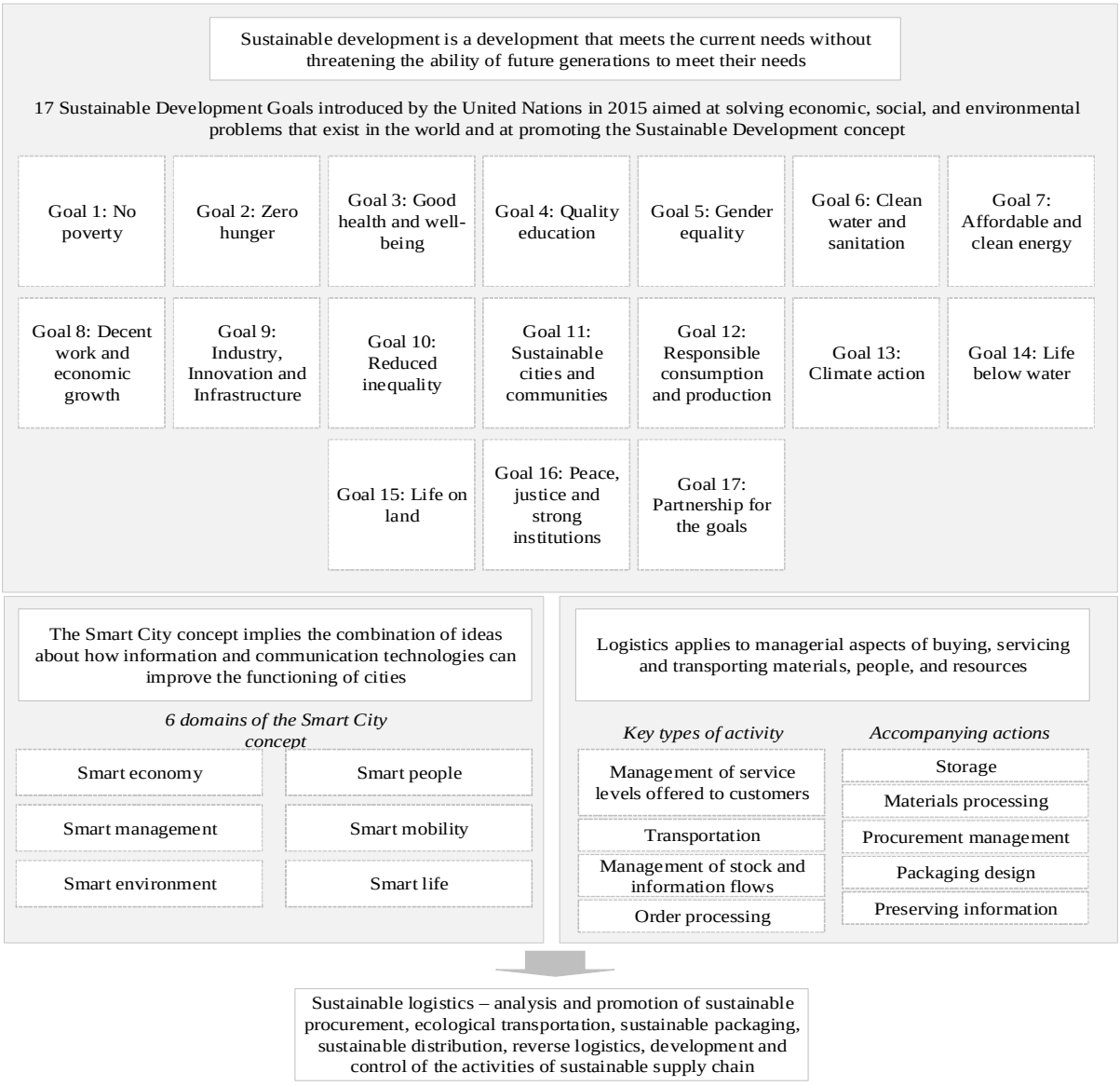

Figure 1 Conceptual framework of the research

Source: prepared and summarized by the authors based on [21,24].

The relationships in Figure 1 are interpreted as follows: smart cities must be developed with the unconditional consideration of the SDGs because of the defined domains of the Smart City concept. In turn, one of these domains is smart mobility, which primarily concerns the logistics system. At the same time, logistics must be sustainable in order to comply with the concept of sustainable development. So, modern logistics companies should care not only about profit maximization and market position but also about environmental friendliness and the social vector of activity.

4.2 Infrastructure and logistics of European countries and establishing a link between logistics performance and related areas

To date, many indices and rankings are designed to evaluate logistics performance and related indicators. A comprehensive analysis of the 2022 European E-commerce Report, [34], is worth noting. The Report provides the values of indices and rankings related to infrastructure and logistics of 37 European countries, enabling the clustering of these countries according to the development of infrastructure and logistics. The cluster analysis determined that the optimal distribution is the clustering of the studied countries into three clusters, which is confirmed by evaluating the average graphs for each cluster (Figure 2).

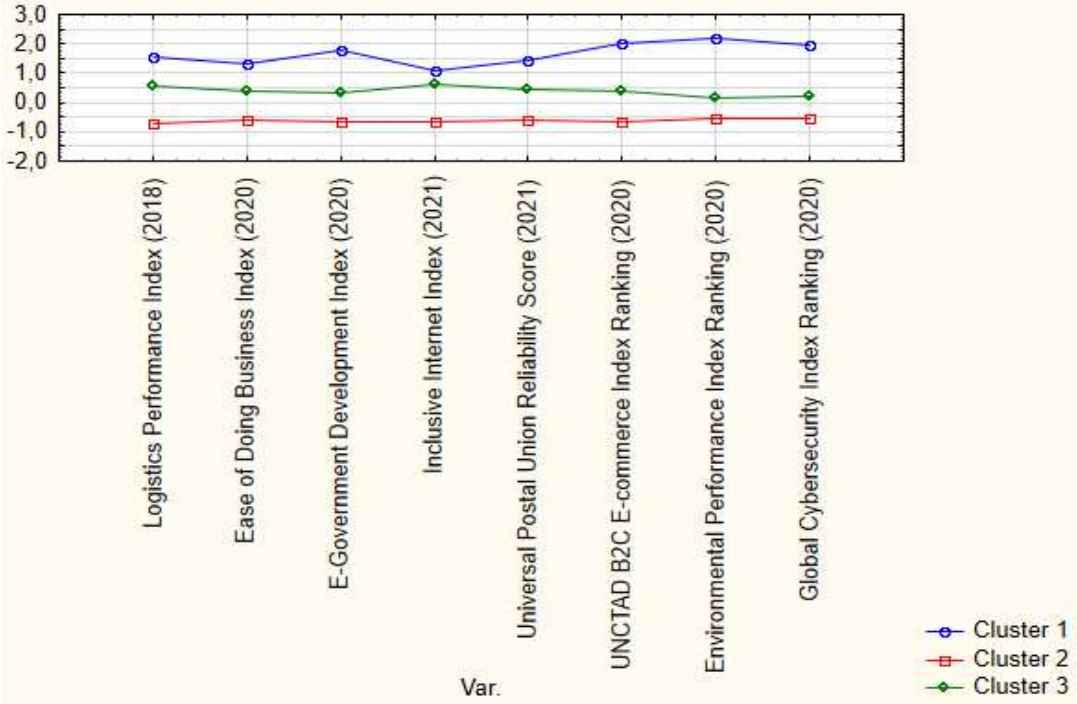

Figure 2 Averages graphs for clusters

The following clusters were identified as a result of the conducted cluster analysis:

Cluster 1 (Cluster with insufficiently developed infrastructure and logistics): Albania, Bosnia and Herzegovina, Montenegro, Ukraine;

Cluster 2 (Cluster with developed infrastructure and logistics): Belgium, France, Ireland, Netherlands, United Kingdom, Denmark, Germany, Estonia, Finland, Lithuania, Norway, Sweden, Austria, Czech Republic, Poland, Switzerland, Italy, Portugal, Spain;

Cluster 3 (Cluster with medium indicators of infrastructure and logistics): Luxembourg, Iceland, Latvia, Hungary, Slovakia, Slovenia, Bulgaria, Croatia, North Macedonia, Romania, Serbia, Cyprus, Greece, Malta.

The Cluster with developed infrastructure and logistics includes countries where individual cities belong to the most developed smart cities in the world. Such cities include London (United Kingdom), Amsterdam (Netherlands), Paris (France), Copenhagen (Denmark), Berlin (Germany), Vienna (Austria). Reykjavik, the capital of Iceland, which also belongs to the most developed smart cities, was included in the Cluster with medium indicators of infrastructure and logistics.

In the context of the study, the countries' Logistics Performance Index is of particular scientific interest among the above-mentioned indices. Table 2 shows how closely this index correlates with all other indices.

Table 2 Results of the correlation analysis of the Logistics Performance Index with other indices

	Logistics Performance Index (2018)
Ease of Doing Business Index (2020)	0.461359
E-Government Development Index (2020)	0.733859
Inclusive Internet Index (2021)	0.637742
Universal Postal Union Reliability Score (2021)	0.652973
UNCTAD B2C E-commerce Index Ranking (2020)	0.834518
Environmental Performance Index Ranking (2020)	0.838396
Global Cybersecurity Index Ranking (2020)	0.571861

The results of the calculations give grounds to conclude that the closest correlation is observed between the Logistics Performance Index and the E-government Development Index, the UNCTAD B2C E-commerce Index, and the Environmental Performance Index.

4.3 The impact of e-commerce development indicators on the profit of international logistics companies

The literature review shows that e-commerce has the most significant impact on logistics processes, particularly in the context of the evolution of smart cities. It is proposed to analyze whether e-commerce indicators affect logistics companies' profit in passenger transportation. They include GAL-VSESVIT LLC, East-European Travel Joint Ukrainian-English Company and GUNSEL LLC. The dynamics of these companies' net profit (NP) and net income (NI) are shown in Figures 3 and 4, respectively.

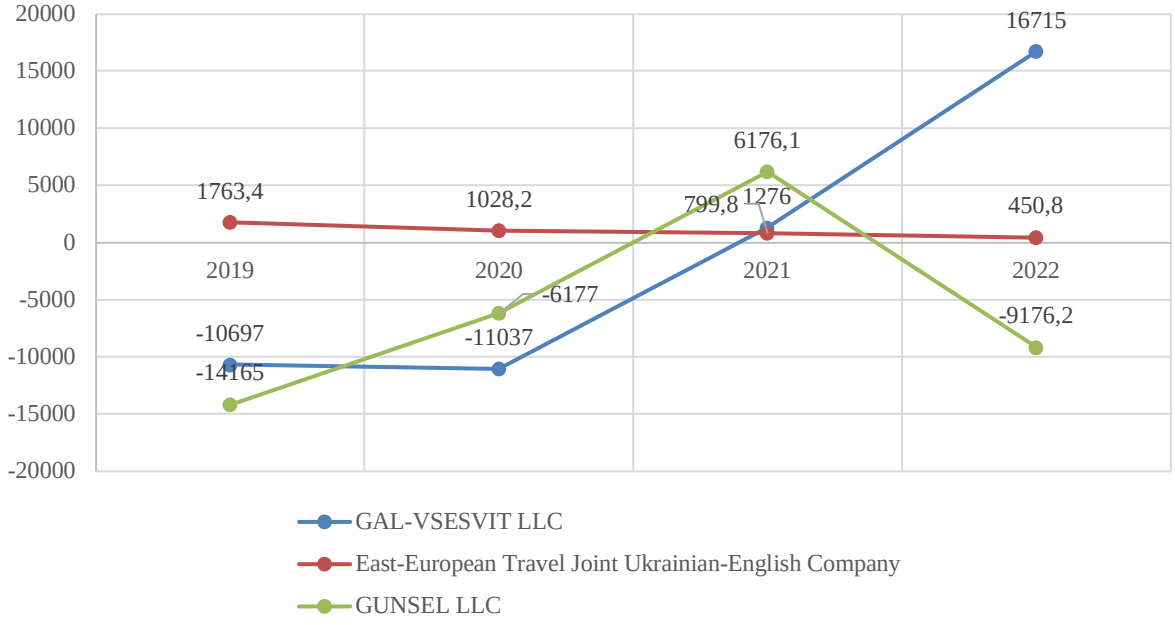

Figure 3 Dynamics of net profit of the studied companies for 2019-2022
Source: built by the authors based on [35].

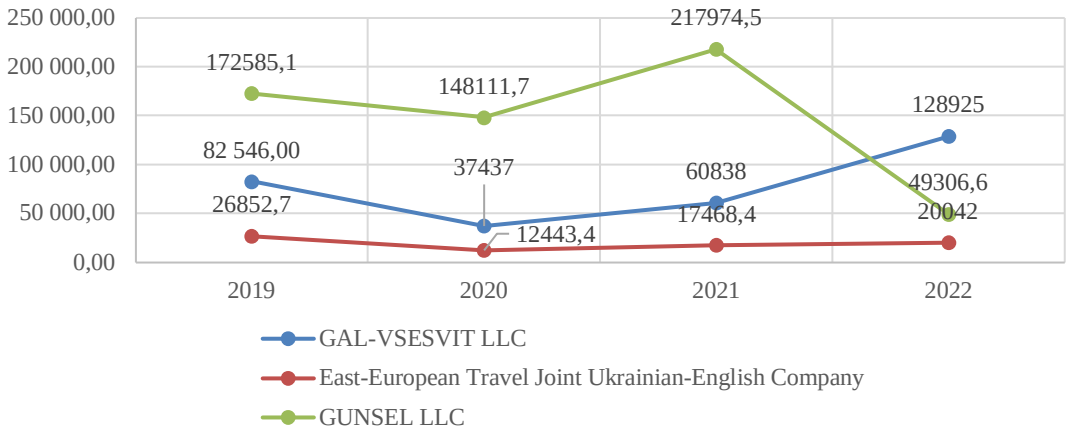

Figure 4 Dynamics of net income of the studied companies for 2019-2022
Source: built by the authors based on [35].

Table 3 shows the results of the correlation analysis between, on the one hand, NP and NI of the studied companies and, on the other hand, e-commerce indicators.

Table 3 Results of the correlation analysis of the Logistics Performance Index with other indices

	Online buyers in Europe	Online buyers in Ukraine	The volume of the e-commerce market in Ukraine	The share of e-commerce	Dynamics of global volumes of electronic retail sales
GAL-VSESVIT LLC (NI)	0.138405	0.492397	0.412681	0.209775	0.563695
GAL-VSESVIT LLC (NP)	0.622232	0.910981	0.859204	0.735323	0.942840
East-European Travel Joint Ukrainian-English Company (NI)	-0.754016	-0.384464	-0.494366	-0.657519	-0.306671
East-European Travel Joint Ukrainian-English Company (NP)	-0.938956	-0.980955	-0.997059	-0.990541	-0.962165
GUNSEL LLC (NI)	-0.527521	-0.526190	-0.544983	-0.413473	-0.560480
GUNSEL LLC (NP)	0.384889	0.435950	0.430593	0.554566	0.383901

The obtained results give grounds to assert that NP of GAL-VSESVIT LLC, NI and NP of East-European Travel Joint Ukrainian-English Company are, to the greatest extent, related to the dynamics of e-commerce indicators — both in Ukraine, in Europe, and the world. No significant relationship was found between other indicators of the state of NP and NI of companies and the studied e-commerce indicators.

5 Discussion

The growing share of e-commerce and its high impact on logistics processes can contribute to the growth of many threats, particularly the natural environment. The response should be the introduction of new approaches and business models by logistics companies, which should focus on ensuring sustainability, environmental friendliness, and social orientation, which will correspond to the Sustainable Logistics in a Smart City concept.

Authors, [26], conclude that transportation and delivery of goods, public transport services, and traffic are crucial elements of a smart city. Researchers, [27], established a causal relationship between logistics performance and economic development. So, in these works, the researchers, like the author of this article, identify logistics and passenger transport as one of the pillars on which a smart city is built.

Researchers, [22], note that the cities striving to become "smart" resort to applying ICT to improve their economy, transport system, traffic management, ecology and citizen welfare. This study is aimed at analyzing literature and, unlike the author's study, does not contain an analysis of actual indicators of logistics in smart cities. However, the researchers consider the impact of e-commerce, as in this study.

In work, [28], established that the use of ICT significantly affects the development of smart logistics, which, in turn, positively impacts the smart city environment, increasing social and economic indicators. The practical value of the study is to inform managers about the application of telematics-based smart logistics. At the same time, the author's research is focused on the need for practical implementation of e-commerce in logistics enterprises.

Some works reveal related aspects not explored in this article. Authors, [20], note that the city's evolution into a Smart City should primarily be based on considering various types of standards, including international ones. This research topic concerns the legal aspects of the problem, while the author's article is economic.

In work, [23], focus directly on the Sustainable Logistics concept. The researchers supplement their work with a list of harmful effects of logistics systems, which necessitate the transition to sustainability. Such effects include harmful emissions, traffic jams, accidents and noise. This study is a literature review, while the author's article quantifies the indicated effects by considering several indices related to the logistics performance in different countries.

Many studies aim to develop specific recommendations regarding the transformation of the logistics system. Researchers, [4], suggest increasing route planning efficiency, using environmentally safe vehicles, and implementing holistic strategic planning to transform the logistics system based on sustainability. As in the author's study, the researchers used a cluster analysis of the logistics performance of several European capitals, but e-commerce indicators were not considered. Authors, [24], note that the selection and determination of the method of transportation, the strategy of programming and routing vehicles, and the level of service can contribute to the effective transformation of the logistics system. In work, [25], propose the quantitative determination of greenhouse gas emissions by logistics centers to ensure their climate neutrality and sustainability, which will enable assessing the use of resources and increase the efficiency of operations.

Paskannaya and Shaban, [29], list directions for introducing green logistics into the Smart City concept: urban planning, reducing traffic jams, harmful emissions and noise and reducing transportation costs. In the mentioned studies, the researchers reach a common conclusion that sustainable logistics is, first, a forced necessity in the current conditions. Second, it should be aimed at ensuring environmental and social benefits. Third, it should be embedded into the Smart City concept as its integral part. Fourth, it should develop with the direct involvement of modern ICT. These conclusions are confirmed by the analysis results conducted in the author's article. This study differs by analyzing the mutual influence of the development of logistics and electronic commerce in quantitative terms, the study of the dependence of the profit and income of logistics companies on the e-commerce development indicators. This topic needs to be covered more in the studies. However, in the author's opinion, e-commerce is a crucial factor in the growth of demand for logistics services, particularly in the B2C sector. Authors, [31], reveal the challenges associated with the rapid development of the e-commerce market and supply chains, namely the sustainability and security aspects. Accordingly, researchers focus on the problem of transport routing in the B2B sector and by trying to tackle the last-mile problem in urban logistics. A comparison of this study with the author's article gives grounds to propose the identification of differences in the transformation of the logistics system based on sustainable development in the B2B, B2C and B2G sectors as one of the potential directions of further research.

6 Conclusions

The analysis carried out in the article led to the conclusion that the Sustainable Logistics concept is closely related to the Sustainable Development and Smart City concepts. In many ways, the interrelation of these concepts is determined by the high impact of modern ICT. The analysis determined that the development of ICT causes an increase in the number of Internet buyers and the share of online trade in the total volume of retail trade. In turn, e-commerce significantly impacts logistics development, new logistics companies' emergence, and increased sales volume. The study found a significant correlation between the net profit and net income of the studied logistics companies engaged in passenger transportation and the dynamics of e-commerce indicators. The results obtained during the conducted correlation analysis give grounds to note that GAL-VSESVIT LLC's net profit and the net income of East-European Travel Joint Ukrainian-English Company are mostly related to the dynamics of e-commerce indicators. These indicators include the percentage of online buyers in Europe and the percentage of online buyers in Ukraine (from the total number of Internet users), the volume of the e-commerce market in Ukraine, the share of e-commerce in Ukraine and the dynamics of global e-retail sales.

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The improvement of the production process performance through material flow and storage efficiency increases serial production

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Keywords: lean manufacturing, material flow, production system, warehouse management, workplace layout.
Abstract: In the current era is increasing intention for identifying and mitigating production bottlenecks, particularly in industrial enterprises, by optimizing material and information within the broader context of enterprise logistics. In industrial practice, when applying lean management or any innovation i.e. change in the production process, a common problem is the lack of knowledge of the value stream as a complete system. The efforts of industrial engineers to streamline material flow and warehouse management are closely linked to the reduction of financial resources associated with operations. The paper is focused on improving performance of production process though material flow and storage efficiency increase. The aim of this paper is to describe the implemented analysis of the material and information flow of a selected product and explain the proposed solution to streamline the warehousing system in an industrial enterprise. Desired result was to adjust the size of warehouse at the line, to save production space and to optimize production process in order to maximize the proportion of time in which value is added to the product in the total continuous production time. Different methods (mathematical-statistical calculations, MIFA analysis, MIFD method, guided interview method, observation, GEMBA walk) have been used in the analysis of the current situation. In current turbulent times, when industrial enterprises are pushed to continuously innovate in order to reduce warehousing capacities, it is necessary to continuously improve performance in the context of sustainable business.

1 Introduction

Given the current challenges of the time, it is necessary to look for bottlenecks in the production process and eliminate them to a minimum. Organizations, but preferably industrial enterprises, are trying to save and discover the potential of activities that could bring more added value to the company. If they focus on their internal processes, they primarily follow material, information and financial flow [1,2]. Enterprise logistics is an inclusive term for the complete logistics of the entire enterprise [3]. The term refers to all logistics aspects both internal and beyond the enterprise. The main aspects of enterprise logistics include supply, internal logistics of production, dispatch and distribution of manufactured goods [4]. The purposeful use of logistics that is based on the immediate needs and interests of one enterprise is usually referred to as enterprise logistics [4,5]. In business practice, there are a number of issues that enterprise logistics has to solve. Among the most common issues are [6,7]: transportation (choice of mode of transport, choice of means of transport, etc.), allocation (optimization and placement of products, distribution warehouses, optimization of capacity utilization in production, material handling), assignment (assignment of employees and machines), priorities (in orders, services), optimization of loading operations, optimum utilization of resources. True optimal management of enterprise logistics processes helps to ensure the smooth operation of the entire enterprise [8].

Hence, most of the issues related to enterprise logistics are related to material flow management. It is the material flow, that is the majority part of manufacturing enterprises and without effective problem solving, it is impossible to ensure the optimal transformation process of the enterprise. Material flow is defined as the movement of material in the production process, including storage [9]. In a broad sense, it starts with the unloading of material on the company's

territory, leads through warehouses, production and ends with the dispatch of finished products or waste on the company's territory [10]. The material flow includes all types of materials that are needed to carry out the production process, as well as their movement in the process [11]. Logistics systems are networks for the distribution of goods using transformation processes that create material flow through the coordinated movement of goods [12]. Figure 1 shows a graphical representation of material flow in the frame of enterprise logistics.

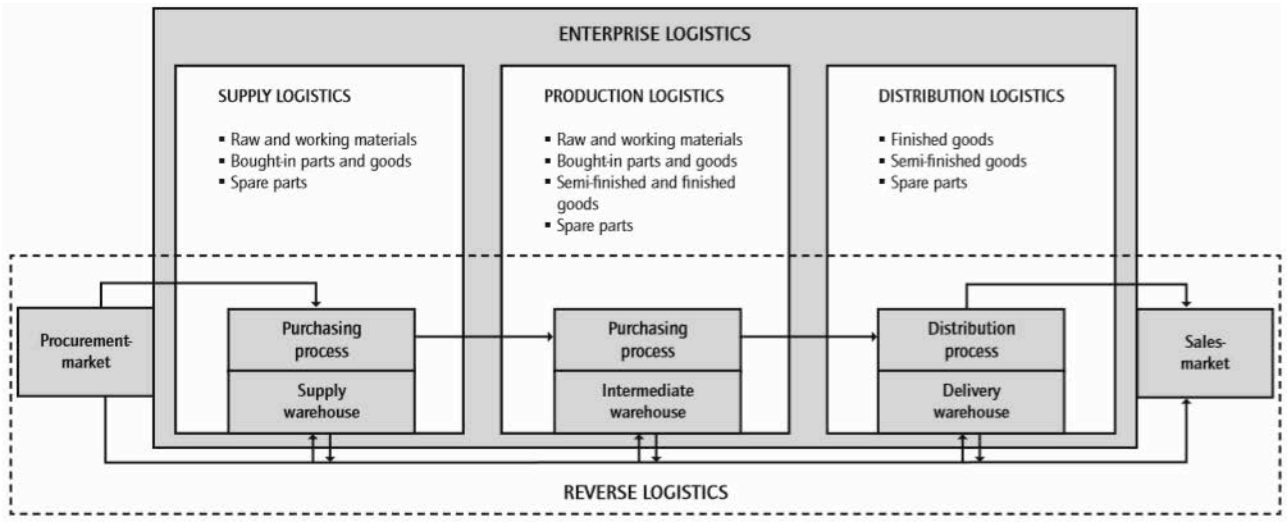

Figure 1 Logistics system according to material flow phases in an industrial enterprise [13]

As can be seen in Figure 1, the material flow of an enterprise is closely related to the supply chains, the internal logistics as well as all production processes of the enterprise [13]. In order to implement material flows, the coordination of personnel, technical resources (machines, vehicles, freight units), inventories, space utilization, information and energy flows must be organized [14]. These include, on the one hand, the processes of transport, handling, storage, packaging and labelling that constitute and support the material flow, on the other hand, order handling and order processing and all related information management and communication flows. Material flow mainly includes [15]:

- actual movement in space - transport, handling,
- storage of finished products in the warehouse of the manufacturing enterprise,
- storage in the warehouse of a trading, supply, sales organization,
- preparation of products for the working shift.

The goal of an efficiently designed material flow is the economical movement of passive elements (materials, raw materials, semi-finished products, products) provided by active elements (transport, handling and storage systems) [9]. A straightforward and simple flow is considered to be the basis of efficiency, which depends on the optimal spatial distribution in the enterprise for both production and warehouse objects [1]. Also important is the low frequency of material flow, which allows the formation of larger, yet volume-integrated handling units that are handled as a single piece when using mechanization means [16]. The main objective is to design better technical and organizational solutions for material flows in production and circulation, not only by mechanizing or optimizing handling operations, but also by optimizing information systems in time and space [8,15]. Closely related to material flow is information and energy flow, which is directly related to the provision of material flow [17]. The industrial practice of the 21st century is directly related to the provision of information flow, which ensures the smooth and running of the material flow along with the running of the entire enterprise [18]. In the case of streamlining material flow, it is necessary to implement enterprise information systems that are based on the principle of collecting data from the entire information flow, which is related to the provision of enterprise logistics [19]. It is the information flow that is directly related to smart enterprise logistics system solutions.

Warehousing is one of the most important parts of the logistics system, which provides storage of products at the point of origin and between the point of origin and the point of consumption [20]. Warehousing allows bridging space and time in the production system. Production inventories ensure the continuity of production, while trade goods inventories ensure the continuous supply of the market. The fundamental role of warehousing is to volume balance and align differently sized material flows within the enterprise [9]. Lean management has now come to the fore mainly in the field of warehousing, the main reason being to minimize the costs associated with warehousing. Trends in lean management will further eliminate warehouse

capacity in the future, either due to more efficient use of warehouse space or to reduce warehouse costs [16,21].

Due to the fact that many business entities do not perceive the management of the enterprise as an integrated system, duplication of measures arises, which are often ineffective [22]. Logistics can be considered as an integrated discipline that integrates the management of the three basic flows in an enterprise (material, information and financial) [19]. If industrial enterprises have to succeed in today's turbulently changing business environment, it is necessary to address management in the context of lean management and the application of optimization and racialization methods [18,20].

2 Materials and methods

Value Stream Mapping in Western European countries is strongly influenced by the lean philosophy, which together with the Value Stream Mapping is VSM method has also spread into Slovakia. From Toyota of Japan came the concept of Material and Information Flow Analysis is MIFA and Material and Information Flow Diagram is MIFD, which gradually began to be adopted by other organizations that applied lean manufacturing [23]. Among the first authors dealing with value flow and its analysis are Mike Rother and John Shook, who published the book "Learning to See" in 1999 [7,21]. The MIFA method is a lean manufacturing analytical tool that maps manufacturing, logistics and management processes in a clear and detailed way. The aforementioned insight is implemented in MIFD, which represents the first step of the streamlining process within the described analysis. Based on the customer requirements and the possible production capacities of the manufacturer, the MIFA and subsequently the MIFD can be implemented.

The basic attributes of MIFA are the respect of the principle of conservation of material (matter) so that the system under study is represented by processes, stocks and monitored flows. The system under study is specified by a system boundary defined in terms of a reference space, a reference time frame and one or more reference materials. The reference time frame may be a time period, such as a year, a month, a week, or a specific date, such as an end of the reference period (e.g. end of a year) [24]. The constructed analyzed flow diagrams display the analyzed information by distinguishing between transformation, distribution and storage processes. Material inventory and flow data are also visualized using other types of diagrams, such as Sankey diagrams and system dynamics diagrams, which show some of the attributes analyzed [25].

The aim of the implemented analysis was to identify bottlenecks in the material and information flow of the production of the selected product using lean management methods. The purpose of the implemented analysis was to propose a solution to streamline the warehousing system in the selected company and to increase the efficiency of the production process.

3 Resulting design of efficient material and information flow

The following part of the paper covers the analysis using the MIFA method, as well as the solution resulting from the analysis, which aimed to rationalise the material and information flow. Storage is an integral part of the production system. The basic functions of warehousing include the quantitative and time balancing of differently sized material flows [26]. However, it is perceived negatively in the principle of downsizing and companies should try to reduce warehousing to a minimum if it is not a technological warehouse [2]. Therefore, the authors of the proposal focused on the optimization of storage in the production process. The first warehouse with optimization potential is the warehouse of components, which is located in the first part of the product assembly. The product is pressed in the plant and hung in the hook warehouse at the press shop, from which the logistics operator moves it on a handling trolley (the parts are still hanging on the hooks) to the warehouse at the assembly. Eight parts are hung on one hook. These parts are pressed in three versions, so their supply must be computer-controlled. Currently there is space for two rows of full hooks and one branch for empty hooks in the warehouse. In total, the built-up area in the line can be defined at 2.66 x 8.10 m, which is 21.55 m^2. In the new layout we propose only one branch for parts and one for empty hooks.

3.1 MIFA analysis

The first step in mapping the value in MIFA is the customer analysis. Due to the fact that the stimulus for production are orders from the customer, the MIFA analysis starts as if from the end of the production process. In the analysed industrial enterprise, there are working two shifts, the morning that works from 6:00 am to 2:00 pm and the afternoon shift from 2:00 pm to 10:00 pm. The break time is set at 30 minutes during the working shift. It follows that the net production (working) time is 15 hours (1). The authors of the proposal considered a 40 working week year, and the customer has placed an order for 798 products.

$$Tact\ Time = \frac{production\ time/day\ (daily\ production\ time)}{ordered\ volume/day\ (daily\ ordered\ volumes)} = \frac{54000}{798} = 68\ s. \quad (1)$$

The customer is in close proximity to analysed enterprise, which represents a Just in Time is JIT supplier. The location of customer is approximately 90 km away from the industrial enterprise under analysis, which represents approximately 80 minutes of transport time for the finished products in a truck. The customer sends orders for 62 references (options), i.e. finished products. Currently 3 basic versions of the final product are produced. All three products can be customised and supplemented with different variants according to individual requirements, resulting in the aforementioned

62 options, a mix of which the industrial enterprise orders from its supplier. Fixed orders arrive every Monday morning, with orders being issued Tuesday to Monday for the whole week for each single truck. Forecast orders are available to the logistics plant staff for one month in advance, but these can still be changed by the customer as required. In the analysed enterprise, orders are processed by the Customer Contact and the Master Scheduler. The orders information is used in the Plan Directeur de Production is PDP meeting, where production for the following week is planned. The PDP meeting is held every Thursday and is attended by the Plant Director, the PC&L Manager, the Master Scheduler, all UAP managers (assembly, press shop, paint Shop), the HR Manager, the FES Specialist and the maintenance Coordinator. In the meeting, weekly production, finished goods warehouses, required number of production staff, production time and maintenance are planned together on a daily basis. The meeting where the transportation plan is created once a month (every third Thursday) is called PIC (plan industrial et commercial) and is attended by the same persons as the PDP meetings. The transport plan (estimated for 6 months) is then updated on the basis of the weekly PDP and information from the material planner, i.e. the logistician, who plans the supplier orders on the basis of the PDP (planned production). From the transportation plan, a board-truck arrival plan is created, which is placed in the truck receiving area in the office of the administrators. Pick up sheets are also generated and sent with the orders to the suppliers, which is one of the tasks of the material planners.

The second step is supplier analysis. This information flow takes us to the other end of the production chain, to the suppliers. We can divide the purchased parts in the company into 3 basic groups:

- Bought Out Parts is BOP - parts that are purchased by the industrial enterprise and enter the product in the production process,
- PLS - parts that the industrial enterprise buys and sends to customers according to orders (no technological process takes place),
- Raw Material is RM - raw materials, which is considered to be the granulate used for pressing and the inks used for painting the parts.

The granulate used for moulding plastic parts for NSF IP is purchased by the company from 4 suppliers. The material planner sends fixed orders and forecasts to these four suppliers, depending on the agreement and contract, how often and for how long. Regarding the transport of material to the industrial plant we attach a summary table (Table 1).

Receiving an order from a customer starts the information flow in the enterprise. When the truck arrives at the plant and is let in from the gatehouse by the administrator to the unloading position, the material (granulate) is unloaded into the annex, where it has its storage place. It takes the A2 operator approximately 60 minutes to unload and store the material (granulate). He uses a forklift to unload, taking one octabin (an octagonal transport box designed for bulk material, that can be made to customer requirements) of granulate per turn on the skids. He places the octabins in the designated places in the annexe next to the tunnel with unloading positions. Each of the materials (granulates) has a storage capacity of 4 rows of 7 octabins (approximately 30 tons of material). For each of the materials (granulates), there is a storage capacity of 4 rows of 7 octabins (approximately 30 tonnes of material).

Table 1 Summary of granulate suppliers (Based on internal company sources, 2020)

Supplier	Distance	Transport time	Delivery frequency	Truck capacity
Supplier 1	958 km	10 hours	1/4 weeks	22 octabins
Supplier 2	1330 km	13.5 hours	1/5 days	22 octabins
Supplier 3	1100 km	11 hours	1/4 days	22 octabins
Supplier 4	35 km	0.6 hours	1/2 weeks	22 octabins

The third step is the analysis of the finished products, which the operator at the second final control places in a container next to the line. The container fits 6 finished products that are not mixed. There are products of one type in one container. That is the reason why there are 3 containers, so that in case of a long polishing or other problem, other final products can be finalised. The logistics operator Picker A2 picks up the parts every 10 minutes or so, and after printing the delivery form and scanning the galley, takes them to one of the three TPAs. The TPA (Truck Preperation Area) is place, where the finished products are stored prior to loading in the composition and number that will be loaded onto the customer's truck. Two products are always picked and serve as safety stock at the same time and one is always in the process of being prepared. The capacity of one TPA is 34 containers, that represents 204 parts, and this is also the quantity transported in one truck. The trucks go to the customer 4 times a day. The arrival times at the industrial enterprise are: 08:30, 10:00, 13:00 and 16:00. It takes 60 minutes to unload the empty packages, load the full ones and process the delivery forms.

The fourth step of the MIFA method is creation of a graph, which is also considered as the output of MIFA (Material and Information flow analysis) or the diagram from the analysis which is a lead time diagram, i.e. a time diagram of the entire production process together with the transportation of material and storage. The shape of this diagram can be seen in Figure 2, where it is in a very reduced form extracted from the MIFD.

The improvement of the production process performance through material flow and storage efficiency increases serial production

Helena Makysova, Filip Galgoci, Zdenka Gyurak Babelova, Augustin Starecek

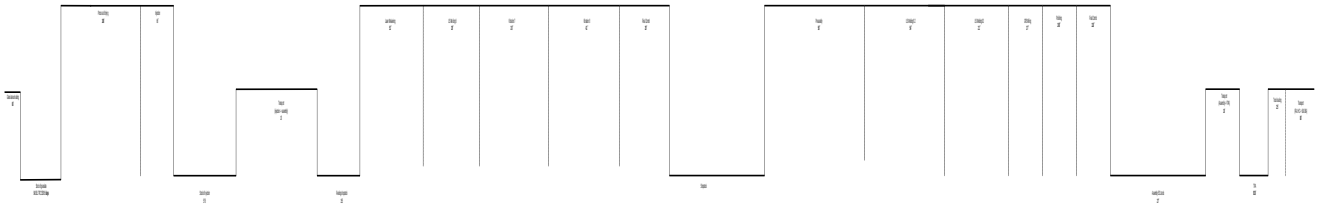

Figure 2 Shape of lead time diagram from MIFD (Own elaboration, 2020)

The whole process is divided into three levels:

- production time - when the actual value is added to the product (the highest part of the diagram) (2),
- transport time - when the material or product is moved (lower part of the diagram) (3),
- storage time - when the material or product is stored in the plant (middle part of the diagram) (4).

$$Production\ time\ [\%] = \frac{Production\ process\ time}{Total\ time} = \frac{3.2}{174.4} = 1.83\% \quad (2)$$

$$Transport\ time\ [\%] = \frac{Transport\ time}{Total\ time} = \frac{1.8}{174.4} = 1.00\% \quad (3)$$

$$Storage\ time\ [\%] = \frac{Storage\ time}{Total\ time} = \frac{169.4}{174.4} = 97.16\% \quad (4)$$

We chose the product TC for analysis because it enters the production process first and thus has the longest production time. The total continuous production time is 174.4 hours from the arrival of raw material to the loading of the finished part into the truck. This time is divided into 3 categories (Table 2). Where the contribution of each activity to the total time is also calculated. The actual value added to the product is only 1.83% of the total continuous production time. The largest part of this time is warehousing, which accounts for more than 96%.

Table 2 Total continuous IP production time divided into 3 categories from MIFD (Own elaboration, 2020)

Name/ Values	Seconds	Minutes	Hours	Percent [%]
Production process	11 517	192	3.2	1.83
Transport	6 300	105	1.8	1.00
Storage	**609 900**	**10 165**	**169.4**	**97.16**
Total	627 717	10 461.95	174.4	100.00

The performed MIFA analysis shows that storage is the bottleneck in the product manufacturing process. From the carried-out analysis conclusions were developed, presented in the following section.

3.2 Conclusions from the analysis

Within the framework of the analysis, the material and information flow of the selected product was mapped in detail. The lean manufacturing tool MIFA was used in the implementation of the analysis and created a MIFD value stream map. In Figure 3, we can see the visualization of material and information flow in the selected industrial enterprise for the selected product.

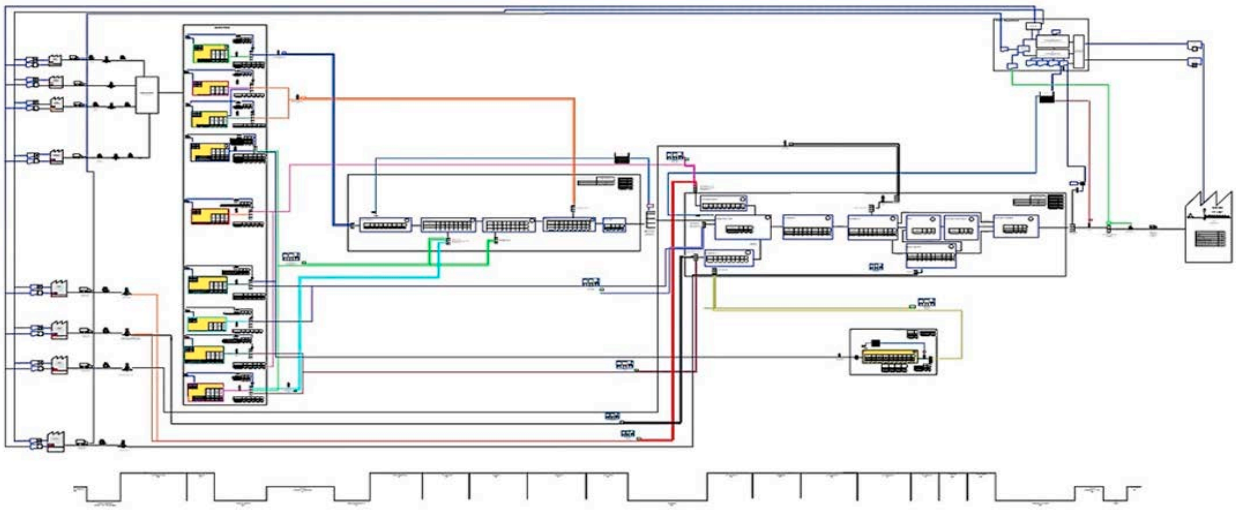

Figure 3 Material and Information Flow Diagram for the selected product (own elaboration, 2020)

The material and information flow map comprehensively maps the production process flow from suppliers to the end customer. Production process flow does not only mean the flow of material, but also the flow of information that precedes the flow of material. The main objective of the MIFA method is to reveal production flow potentials and change opportunities in the whole process. The result indicator is the proportion of time in which value is added to the product in the total continuous production time. The objective is to maximize that proportion and to do so to some extent by reducing material storage and transportation time. As mentioned above storage in the production process came out as risky and hence there was scope for designing a comprehensive measure to streamline the production process in the selected enterprise in Slovakia.

3.3 Calculation of the necessary storage capacity

With a production volume of 798 products and a net production time of 20.25 hours, the hourly production is 40 units of products. The infeed warehouse at the line is stocked by an operator who has a 10 minute circuit. This means that every 10 minutes he brings 8 pieces of products on the hook. According to the company's internal rules, the assembly warehouse should have a capacity of 2x the cycle time of the supply train or the operator (adequate to production) plus one extra pack. This means that if the parts were supplied by a milkrun (30 minute cycle time) the warehouse would have to have capacity for an hour's production. In the above case, the warehouse would only need to have capacity for 20 minutes of production plus one hook. This equates to 3 hooks and 24 pieces. Current capacity is 2 rows of 6 hooks, totally 12 hooks (96 parts). The proposed capacity is 1 row with 6 hooks, which means 48 parts in stock. Thus the requirement of 24 pieces remains unfulfilled.

Another warehouse that is, based on the analysis, unnecessarily large is the Defroster Duct is DD warehouse. Similar to the Top Cover is TC components warehouse, the part is pressed in-house and transported internally on hooks. There are more similarities in the handling of this component, such as the same logistics operator handling the components from the press shop warehouse to the assembly warehouse, or the same capacity on a single hook. The difference between handling of these components is that in the line, this warehouse is located next to the TC warehouse and occupies an area of 2.09x8.1m = 16.93 m^2. There are also two rows for full hooks and one return branch.

As a further change related to the reduction of the above-mentioned warehouses, we propose to mirror turn the line and thus bring the warehouses for TC and DD closer to the press shop warehouse. The distance between warehouse will be reduced by approx. 15 m for 8 components (1 hook). This means that with a daily capacity of 798 products, the indicated distance will be traversed 200 times (2 parts). In one shift, the operator thus walks approximately 1 km less (time saving of approx. 50 minutes). From the opposite side, the parts will be supplied by a train, which can travel on the other side of the line. With the explained solutions, the machines in the line will be brought closer together and the line layout will be made more efficient as can is visualized in the Figure 4.

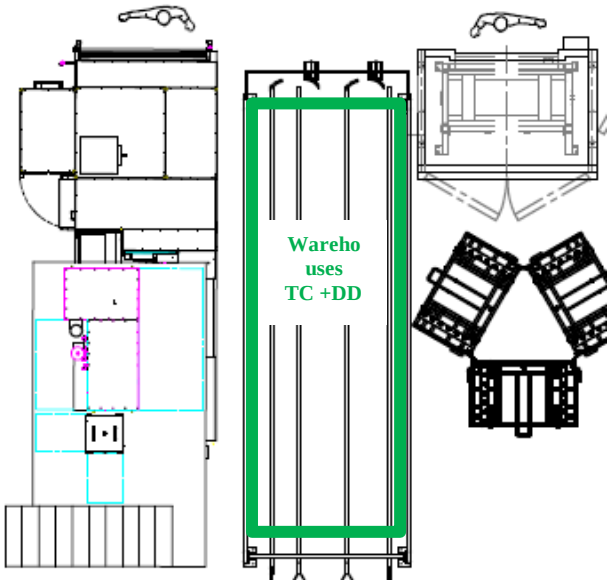

Figure 4 Proposed layout of workplace Assembly 1 with reduced warehouses (Own elaboration, 2020)

In the proposed layout we consider only one full and one empty branch. The capacity calculation would be identical to that for the TC part. Required capacity are 3 hooks (24 parts). Proposed 1 branch have 6 hooks (48 parts). The main idea remains that we are proposing to reduce the storage capacity of 96 parts to 48 parts. The proposed layout will require a change in the stocking of the line in the exact order in which products are produced. The TC part has 3 versions and the DD part has 2 versions. The product is produced in batches, and when a version change is made, the mould must be changed on the welding machines (approximately 15 minutes). According to the Kanban system, the assembly leader 1 has the information to change the production to a different version, and he must inform the logistics operator in time to already supply the necessary parts. The proposal is to introduce the use of hanging boards with the name of the reference, which if the GAP leader hangs in the warehouse, the logistics operator will know that he has to stock other parts. Consequently, the proposal is to retrain the operators working in this position to stock the warehouses according to the above instruction. The intention is not to take parts off the line back to the press shop warehouse when the production reference changes, but to bring only the exact number of parts that will be produced in a given batch to the line.

3.4 Summarization of warehouse optimisation

In an industrial company, the need arose to ensure that the necessary space was found for a new project in the production hall. This means the possibility of relocating machines, changing their place in the line, or adjusting the size of warehouses in order to optimize the production process or save production space. The reduction of the warehouses at the line (TC and DD parts) means a saving of 18.23 m^2 as can be seen in Table 3.

Table 3 Space saving for Assembly Line 1 (Own elaboration, 2020)

Warehouse of component	Current status	Proposed status	Savings
TC	2.66 x 8.1m = 21.55 m^2	1.4 x 8.1m = 11.34 m^2	10.21 m^2
DD	2.09 x 8.1m = 16.93 m^2	1.1 x 8.1m = 8.91 m^2	8.02 m^2
Total	4.75 x 8.1m = 38.48 m^2	2.5 x 8.1m = 20.25 m^2	18.23 m^2

An even greater benefit of the design measure than the savings in storage space is the closer proximity of the machines in the line, as the warehouses are located between the 2 machines. This will reduce the walking time of the operators in each cycle. The estimated saving is 7 seconds per part, a significant time saving for the capacity of the production. Especially in a situation where the line operates in 2 models, where are needed 2 or 3 operators. The third operator is a GAP leader who should not spend most of the working time in the line. The intention of the management is to work with only 2 operators, so any speeding up of the production process is important.

Another significant area saving is the reduction of intermediate storage. In this case, we are talking about an area of 44.1 m^2, calculated as follows: original warehouse area: 7 x14.5 = 101.5 m^2. Proposed warehouse area: 7x8.2 = 57,4 m^2. Area saving: 101.5 – 57.4 = 44.1 m^2. The saved area will be divided on both sides of the warehouse. On one side (where the TC and DD warehouses will be) there will be an area of 4 x 7 = 28 m^2 and on the other side the remaining 2.3 x 7 = 16.1 m^2. On the first area is proposed to create a GAP for the production line. GAP means a meeting area for the TOP 5 for each shift, lockers for employees and boards to keep track of different products related to the production lines. On the other side of the warehouse, there will be space for a rework table and a new welding machine, or other necessary measuring jigs. Compared to the original layout, the transport route is proposed to be shortened and reduced by about 15 metres to 8 parts (1 hook). This means that the operator walks 1 km less per shift when stocking these parts, leaving time for stocking other parts.

4 Conclusion

At the industrial plant where the analysis was carried out, it was decided that the NSF line would be moved to provide the necessary space in the production hall for the new project. By applying the chosen methods and implementing the proposed changes, it was possible not only to shorten and simplify the material flow, but also to optimize the production process and save production area. The reduction of the warehouses at the line (TC and DD parts) means a saving of 18.23 m2. An even greater benefit was the saving of the warehouse area thus shortening the walking time of the operators in each cycle. The dog time to simulate the process is not known, but the estimate is 7 seconds per part, a significant time saving at the size of the production. Especially in a situation where the line operates in 2 models - 2 or 3 operators. The goal was to run the procees with only two operators, which was achieved by the optimization implemented. Another benefit was that, compared to the original proposal, the transport route is proposed to be shortened and by about 15 meters to 8 parts (1 hook). This means that the operator will travel 1 km less per shift when supplying these parts and will have time to supply other parts.

Within the presentation of the carried-out analysis, the product production process was described in terms of material and information flow, which provided an opportunity to develop a proposal for providing and managing change due to the need to create space for a new project. As part of the analysis, a current material flow value map was created, which allows managers, planners, project engineers and other specialists in the company to not only see the value in the material flow, but also to distinguish it from waste and eventually get rid of it [14]. The map allows to identify each process located in the value stream, to clearly define it in the confusing and opaque structure of an industrial enterprise, and to build the value stream based on the principle of lean [17]. It is up to the lead employees of the enterprise how often they use the map and with what frequency to update the data, but at least when changes are made to the product's production process, it will provide an important information base. Based on the analyses performed and the design implemented, it was possible to streamline the production process in the analysed industrial enterprise. The mentioned proposal contributed to the improvement of not only the company logistics, but also ergonomics, production effectiveness, or overall performance of the company.

The MIFA method as well as the above rationalisation process can be used repeatedly or in combination with the use of Just in Time (JIT). It is important to sub-detailed monitor and analyse all the factors analysed. If the inputs are not sufficiently monitored there is a risk of bias in the results after the application of MIFA analysis.

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Analysis of corporate management risks in the work of logistics enterprises
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Analysis of corporate management risks in the work of logistics enterprises

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Keywords: risk, logistics, corporate risk, logistics company, risk management.
Abstract: Relevance of the problem. Complexity in the global supply chain increase the risks that enterprises are exposed to, including logistics. Purpose of the article. The article analyzes the corporate management risks of logistics enterprises. Methods. The article used the method of statistical groupings and statistical tables, the game theory method, the matrix game method. Main results. The study substantiates an algorithm for the analysis of corporate management risks of using blockchain technologies in the activities of logistics companies when concluding smart contracts, certifying new types of transportation, and integrating cryptocurrency for delivery payments. Examples of choosing an economic strategy for managing the risks of a logistics company using the criteria of maximax, Laplace, Wald, Savage, Bayesian, Hurwicz were elaborated. Referring to the relevant calculations, it was determined that the most often recommended strategy was "the certification of new types of logistics services". It was determined that this strategy will contribute to minimizing the logistics company's risks associated with the implementation of blockchain technology through ensuring the competitive position through innovation. Practical relevance. The findings can be useful for managers of logistics companies in practical implementation and use of blockchain technologies as well as in risk management. It is expedient to focus the further research prospects onto the integration of blockchain technology with modern logistics companies' ERP systems in the further developing the Logistics 4.0 concept.

1 Introduction

1.1 Problem statement

Logistics is an important tool in business management, optimizing material and related flows in the sphere of commodity and money circulation [1]. In the processes of goods movement in the market space the logistics system includes various elements, the functioning of which is influenced by certain risk factors [2]. Ensuring stability and reliability at all levels of the logistics system requires careful analysis of relevant risks to anticipate and minimize them.

The transition to digital manufacturing and e-commerce requires a rethinking of the role of logistics as a value chain management tool. Digital transformation raises the need for the changes in logistics in order to adapt it to modern requirements and obtain numerous advantages due to the use of the latest technologies. Digital transformation can accelerate the execution of business processes in supply chains, providing more reliable and transparent information for informed decision-making. This will lead to cost savings by preventing potential risks and eliminating operations that are of no value to customers. The continuum of digital technologies that make up the core functionality of digital logistics includes big data processing and analytics, the Internet of Things, blockchain technology, cloud services, e-logistics, 3D printing, and others. According to global practice, the use of blockchain technology is one of the most promising areas in the information support of logistics services.

Blockchain technology is widely used in various fields due to its unique features. One of these fields is logistics, which often involves multiple stages and numerous geographical locations. This complexity makes it difficult to track events, monitor the transportation of goods, and respond to unforeseen circumstances. Additionally, the lack of transparency makes it challenging to investigate illegal activities along the route. However, blockchain technology can address these issues by providing a transparent public ledger that allows clients and auditors to

track the entire route easily. It is crucial that all members of the supply chain have access to the network to fully utilize blockchain's benefits. By eliminating unnecessary intermediaries, reducing workflow, and ensuring strong security, blockchain technology can prevent errors, illegal labeling of goods, and other fraudulent activities. An additional advantage of using innovative blockchain technology is cost savings for the industry.

The logistics sector is gradually implementing projects that utilize blockchain technology. One such project is being carried out by Maersk, the Danish transport giant, which is exploring ways to automate document flow and manage freight transport more efficiently and transparently. In collaboration with IBM, Maersk is developing its own blockchain technology based on Hyperledger Fabric, which enables the monitoring of millions of container shipments per year and better integration with customs services. Another example is Walmart, the popular US retailer, which is using Hyperledger Fabric in its distributed ledger technology pilot project to track pork leakage in China and its transport and storage in the US. Thus, there are different ways and strategies of implementing blockchain technology in the activities of logistics companies. This makes it necessary to carefully assess the risks of such implementation and define a strategy that will ensure their minimization.

1.2 Research focus

Thus, given that blockchain technology is a way of storing data or a digital register of transactions, agreements, contracts, its main advantage is that this register is not stored in any one place. It is distributed among several hundred or even thousands of computers around the world. Any user of this network can have free access to the current version of the registry, which makes it transparent to absolutely all participants. Logistics is one of the areas where the use of blockchain can increase the efficiency of enterprises, namely, to ensure the transparency of supply chains, reduce costs and risks during logistics operations.

The purpose of the study is to determine the managerial corporate risks of using blockchain technology in a logistics company.

2 Literature review

A considerable number of scientific works are devoted to the study of the risks of the activities of logistics companies. A number of scientists determine the essence and factors of risk formation in logistics activities.

What should be stressed here is that according to researchers the main motive behind risk identification is to identify all significant risks that the supply chain may face. Once relevant risks are identified, the evaluation is carried out to enhance the understanding of each risk and their significance, [3].

In this context authors research is worth highlighting, in which the consider organizations providing logistics services, dynamic changes in the external environment affect the risk of performing processes and compromise effective integration of resources, coordinated operations management and, therefore, negatively affect on customer satisfaction and loyalty, [4,5]. From this perspective such processes require improved management of logistics services and an integrated management concept that combines the integration of processes for analyzing satisfaction and risks that may adversely affect the provision of satisfactory logistics services.

Pokrovskaya et al. [6] state that the results of a logistics audit often reveal the following problems in the logistics system for the delivery of goods: a process control system was not created; there is no complete supply chain control system; there are considerable gaps in the cross-functional interaction of the structural divisions of the company. In fact, the above circumstance is a serious logistical risk, which reduces the reliability and manageability of the supply chain in the logistics system for the delivery of goods and does not allow automating the operation of the enterprise's logistics system. Consequently, there are risks of making untimely or incorrect management decisions in supply chain management, [6].

It is also worth highlighting the studies that systematize the specific risks of logistics companies. For instance, researchers note that the risks associated with the supply chain management process indeed raise many concerns and require the company to be flexible in response. In this regard, various sources of risk including political risk, socio-cultural risk, as well as business risk can lead to weaknesses and inefficiencies in supply chain integration, [7,8].

Authors point out that delays in delivery are usually caused by personal and operating conditions. In this regard, one of the personal conditions causing delivery delays are drivers and technicians who are less agile in carrying out their duties. Moreover, unexpected damage can occur in the operating conditions such as trucks and generators, [9].

Still other scientific papers are devoted to the practical aspects of risk management in logistics companies. In particular, authors argue that one of the most important prerequisites for a successful business is the integration of risk management into business management. The scholars view it as an integral part of company's competitiveness. Increasing costs and complexity in organizations lead to increased uncertainties and risks. This entails an increasingly widespread implementation of the risk management process to reduce risk and thereby avoid deviation from the goal, [10,11].

Wang et al. [12] hold that it is also important to consider the risk on the part of the client, which is primarily associated with the client, for example, request and offer, order receipt, order processing and possible order modification. Customer risk, a type of internal supply chain risk that mainly comes from the customer, can cause controversy and/or affect normal logistics operations at logistics service providers. Correspondingly, researchers focus on the risks associated with customers of logistics companies.

In the same vein, as noted by researchers, supply chains are currently striving to develop recovery and reintegration strategies for end-of-life products. Nevertheless, in these reverse logistics operations certain events can entail financial losses for the company and adverse consequences that damage the environment and society], [1,13].

For another thing, the scholarly works also elaborate on the opinion regarding the risks of using blockchain in the management decisions of logistics companies. For example, Kodym et al. [14] point out that risks arise from both sides, both cybernetic and physical, and companies become more vulnerable in consequence. When utilizing risk models, risk evaluation should beyond question provide risk awareness.

Likewise, authors reasonably note that risks can negatively affect not only internal processes within the company and business results, but also management decisions. Hence, the identification of specific risks would be an indispensable prerequisite for making informed decisions, [15,16].

With all the mentioned aspects, it cannot be denied that current research has practical relevance from the perspective of digitalization economy as one of the groundbreaking means of conducting logistics activities is blockchain technology. Blockchain can be defined as a distributed database solution endorsed by users participating in the network and a regularly growing set of data records or a data record technology that captures and distributes transactions, deals, sales, and contracts, [17].

That having been said, the consideration of risks in logistics activities is an important area of scientific research in various sectors of economy. The scientific enquiry is focused on determining the nature of risks in logistics, directions for managing them, determining the advantages and disadvantages of risk evaluation methods. Probing deeper into the findings of the above scientific studies, it is still relevant to clarify the risks in the corporate segment of logistics companies management.

3 Methodology

The research procedure comprises the following stages:

1. At the first stage of the study, a set of research methods and tools was formed.
2. At the second stage, a sample of the study was formed (three Azerbaijani logistics companies)
3. At the third stage, the corresponding calculations were made using the matrix game methodology, game theory, and the method of statistical groupings and tables.

3.1 Methods

The study used the method of statistical groupings and statistical tables, the game theory method, the matrix game method, which were utilized when choosing a risk management strategy. In particular, the use of statistical groupings and tables made it possible to quantify the degree of homogeneity of the selected data groups in relation to the calculation of the matching criteria, and to select essential grouping features. Grouping of a statistical population begins with the selection of grouping characteristics. The method of statistical groupings establishes only the existence of a relationship between phenomena, without determining its comparative quantitative parameters. For this reason, along with the method of groupings, the method of game theory is further applied. Game theory should be considered as a tool for improving the efficiency of planning and management decisions. With the help of this section of mathematical economics, we investigate the resolution of conflicts between players (logistics companies) and the optimality of their strategies. Conflict in this sense is referred to the distribution of profits. The matrix game method is a finite two-player zero-sum game in which player 1's payoff is represented as a matrix. The row of the matrix corresponds to the number of player 1's strategy, the column corresponds to the number of player 2's strategy; the intersection of the row and column of the matrix is the payoff of player 1 corresponding to the strategies used. The use of a matrix game has provided scientifically sound strategies for coordinating the actions of logistics companies in terms of risk management.

3.2 Sample

The study examined the practice of the Azerbaijani logistics companies Trade Logistic MMC, CLS and Global Logistics Services LLC (selected according to the rating of the CARGO-CARDS portal, based on their first positions in the rating in terms of traffic volume and the rating of trust in the company, [18]). For risk analysis and calculation of game theory criteria, a choice of alternatives in the activities of the companies under study is proposed. These alternatives are as follows: alternative A_1 - the use of blockchain for concluding smart contracts, alternative A_2 - certification of new types of transportation, alternative A_3 - integration of cryptocurrency for payments for deliveries (A_3).

3.3 Tools

To elaborate an economic risk management strategy, the current study used the criteria of maximax, Bayes, Laplace, Wald, Savage, and Hurwicz. The maximax criterion guides statistics towards favorable conditions in the logistics market, in other words this criterion communicates an optimistic evaluation of the situation.

According to the Bayes criterion, the (pure) Ai strategy is taken as optimal, which maximizes the average payoff a or minimizes the average risk r.

With the Laplace criterion, provided that probabilities of state of energy market are plausible, they are evaluated using the Laplace principle of insufficient basis, according to which all states of nature are considered equally probable, i.e. (1), (2).

$$q_1 = q_2 = \ldots = q_n = 1/n. \quad (1)$$

$$q_i = 1/3. \quad (2)$$

According to the Wald criterion, the pure strategy is taken as optimal, which guarantees the maximum payoff under the worst conditions, i.e. (3)

$$a = \max(\min a_{ij}) \quad (3)$$

The Wald criterion focuses statistics on the unfavorable conditions of the logistics market: i. e., this criterion communicates a pessimistic evaluation of the situation.

The Hurwicz criterion is a pessimism – optimism criterion. The optimal strategy is considered to be the one for which the relation is fulfilled as follows (4):

$$\max(s_i) \quad (4)$$

where si = y min(aij) + (1-y)max(aij)

At y=1 we get the Wald criterion, at y=0 we get the optimistic criterion (maximax).

In this regard, the Hurwicz criterion takes into account the possibility of both the worst and the best market behavior for the company. As such, the worse the consequences of erroneous decisions, the greater the desire to insure against mistakes, the closer to 1.

3.4 Data analysis

To determine the economic strategy for managing the risks of using blockchain technology and elaborating the payment matrix, the data on the cost of implementing blockchain technology (mln dollars) and profit from each of the identified alternatives (mln dollars) were used.

4 Results

To analyze the corporate risks of logistics enterprises, we will choose the risk of using blockchain technology in the management of logistics enterprises. In particular, we adddress the following key areas for the application of blockchain technology in logistics enterprises management (Figure 1).

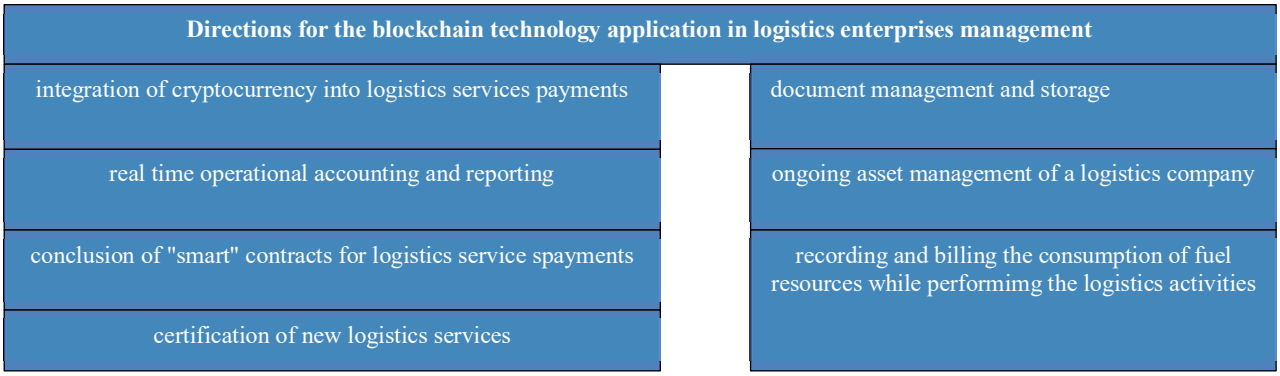

Figure 1 Directions for the blockchain technology application in the corporate logistics enterprises management
Source: compiled by the author based on [12,17,19].

Given that blockchains have a number of advantages, they are not without some downsides. With special reference to the application of blockchains in enterprise logistics management, we systematize the main risks thereof.

1. High energy intensity of the system (the energy consumption of using the blockchain is quite high and requires significant costs).
2. Lack of familiarization and standardization.
3. Cyber security and other technical issues.
4. Accounting difficulties (for example, accountants' lack of knowledge of blockchain technology).
5. Problems of audit practice (lack of sufficient evidence of the transaction nature, guarantees for the classification of transactions in the financial statements of the fuel and energy company, the estimated transactions cost, etc.).
6. Technological barriers (considerable computing power for the transactions to be verified, a huge amount of memory for the transactions history to be stored).

More to the point, it is possible to reduce the risks impact of using blockchain in logistics activities by analyzing the risks thereof in logistics enterprises, which should be carried out in a certain sequence (Figure 2).

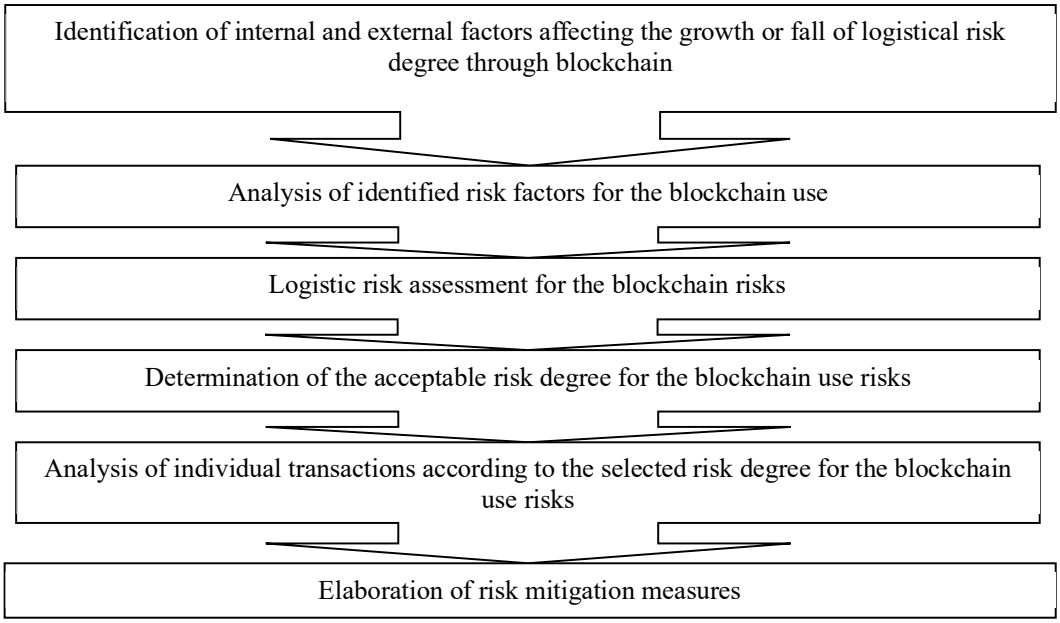

Figure 2 The risk analysis algorithm for the blockchain use risks in a logistics company
Source: author's calculations.

It should be pointed out that while carrying out the research we examined the examples of risk management. The application of the matrix game yielded the following data. The Azerbaijani logistics company Logistic MMC can apply the blockchain for concluding smart contracts (A_1), certifying new types of services (A_2) and integrating cryptocurrency for supply settlements (A_3), while receiving a profit (million dollars), which can be in one of three options (P_1, P_2, P_3) depending on the decision made, namely A_1, A_2 or A_3 (the data taken from the company's activities). The elements of the payoff matrix characterize the profit received in the course of the i-th activity of the companyin the j-th state of demand. The enterprise's game against demand is provided by the payoff matrix. The results of applying the above method are structured in the form of a table below.

As a result of applying the game theory method and the method of statistical groupings and tables, the following data were obtained (Table 1).

Table 1 Criteria for the economic strategy of MMC company risk management

	Logistic MMC company				
Initial data	A_i	P_1	P_2	P_3	
	A_1	10	9	11	
	A_2	15	17	12	
	A_3	10	11	14	
Maximax criterion	A_i	P_1	P_2	P_3	$\max(a_{ij})$
	A_1	10	9	11	11
	A_2	15	17	12	17
	A_3	10	11	14	14
	max=17 (Strategy N=2)				
Bayesian criterion	A_i	P_1	P_2	P_3	$\sum(a_{ij}p_j)$
	A_1	3.3	2.97	3.63	9.9
	A_2	4.95	5.61	3.96	14.52
	A_3	3.3	3.63	4.62	11.55
	p_j	0.33	0.33	0.33	
	max=14.52 (Strategy N=2)				

Laplace criterion

A_i	P_1	P_2	P_3	$\sum(a_{ij})$
A_1	3.333	3	3.667	10
A_2	5	5.667	4	14.667
A_3	3.333	3.667	4.667	11.667
p_j	0.333	0.333	0.333	

max=14.67 (Strategy N=2)

Wald criterion

A_i	P_1	P_2	P_3	Min (a_{ij})
A_1	10	9	11	9
A_2	15	17	12	12
A_3	10	11	14	10

max=12 (Strategy N=2)

Savage criterion

A_i	P_1	P_2	P_3	Max(a_{ij})
A_1	5	8	3	8
A_2	0	0	2	2
A_3	5	6	0	6

min=2 (Strategy N=2)

Hurwicz criterion

A_i	P_1	P_2	P_3	Min (a_{ij})	Max (a_{ij})	y min(a_{ij}) + (1-y)max(a_{ij})
A_1	10	9	11	9	11	10
A_2	15	17	12	12	17	14.5
A_3	10	11	14	10	14	12

Max=14.5 (Strategy N=2)

Source: author's calculations.

Further, we will perform these calculations for the CLS company (Table 2).

Table 2 Criteria for the economic strategy of CLS company risk management

CLS company

Initial data

A_i	P_1	P_2	P_3
A_1	12	10	13
A_2	14	15	14
A_3	11	12	15

Maximax criterion

A_i	P_1	P_1	P_3	max(a_{ij})
A_1	12	10	13	13
A_2	14	15	14	15
A_3	11	12	15	15

max=15 (Strategy N=2)

Bayesian criterion

A_i	P_1	P_2	P_3	$\sum(a_{ij}p_j)$
A_1	3.96	3.3	4.29	11.55
A_2	4.62	4.95	4.62	14.19
A_3	3.63	3.96	4.95	12.54
p_j	0.33	0.33	0.33	

max=14.19 (Strategy N=2)

Laplace criterion

A_i	P_1	P_2	P_3	$\sum(a_{ij})$
A_1	4	3.333	4.333	11.667
A_2	4.667	5	4.667	14.333
A_3	3.667	4	5	12.667
p_j	0.333	0.333	0.333	

max=14.33 (Strategy N=2)

Wald criterion

A_i	P_1	P_2	P_3	Min (a_{ij})
A_1	12	10	13	10
A_2	14	15	14	14
A_3	11	12	15	11

max=14 (Strategy N=2)

Savage criterion

A_i	P_1	P_2	P_3	Max (a_{ij})
A_1	2	5	2	5
A_2	0	0	1	1
A_3	3	3	0	3

min=1 (Strategy N=2)

Hurwicz criterion

A_i	P_1	P_2	P_3	Min (a_{ij})	Max (a_{ij})	y min(a_{ij}) + (1-y)max(a_{ij})
A_1	12	10	13	10	13	11.5
A_2	14	15	14	14	15	14.5
A_3	11	12	15	11	15	13

max=14.5 (Strategy N=2)

Source: author's calculations.

Further, we perform the evaluation of these criteria for the company Global Logistics Services LLC (Table 3).

Table 3 The economic strategy criteria for Global Logistics Services LLC company risk management

CLS company

Initial data

A_i	P_1	P_2	P_3
A_1	11	13	17
A_2	10	15	18
A_3	12	14	19

Minimax criterion

A_i	P_1	P_2	P_3	max(a_{ij})
A_1	11	13	17	17
A_2	10	15	18	18
A_3	12	14	19	19

max=19 (Strategy N=3)

Bayesian criterion

A_i	P_1	P_2	P_3	$\sum(a_{ij}p_j)$
A_1	3.63	4.29	5.61	13.53
A_2	3.3	4.95	5.94	14.19
A_3	3.96	4.62	6.27	14.85
p_j	0.33	0.33	0.33	

max=14.85 (Strategy N=3)

Laplace criterion

A_i	P_1	P_2	P_3	$\sum(a_{ij})$
A_1	3.667	4.333	5.667	13.667
A_2	3.333	5	6	14.333
A_3	4	4.667	6.333	15
p_j	0.333	0.333	0.333	

max=15 (Strategy N=3)

Wald criterion

A_i	P_1	P_2	P_3	Min (a_{ij})
A_1	11	13	17	11
A_2	10	15	18	10
A_3	12	14	19	12

max=12 (Strategy N=3)

Savage criterion

A_i	P_1	P_2	P_3	Max (a_{ij})
A_1	1	2	2	2
A_2	2	0	1	2
A_3	0	1	0	1

min=1 (Strategy N=3)

Hurwicz criterion

A_i	P_1	P_2	P_3	Min (a_{ij})	Max (a_{ij})	y min(a_{ij}) + (1-y)max(a_{ij})
A_1	11	13	17	11	17	14
A_2	10	15	18	10	18	14
A_3	12	14	19	12	19	15.5

max=15.5 (Strategy N=3)

Source: author's calculations.

Thus, because of solving the statistical game according to various criteria, the A_2 strategy proved to be the most often recommended one, in particular the certification of new types of logistics services. Such a strategy in the context of digitalization will ensure the competitive position through innovation and will minimize risks by automating the logistics services processes.

5 Discussion

The current risk analysis algorithm for the use of blockchain technology by logistics enterprises (Figure 1) has common stages with the opinion of researchers. Supply chain research tends to break down risk management into three processes: risk identification, risk evaluation, and risk mitigation. The initial stage of the process starts with risk identification, which is basically considered imperative for risk management, [20,21].

What should be stressed here is that yet other researchers, assigning the risks of the logistics system to a specific category allows one to determine the processes that need to be given special attention when developing the company's logistics strategy, identify weaknesses in logistics, additional costs associated with risk prevention policies, etc., [22,23].

However, Bartosova et al. [24] indicate that the larger the company size, the higher its costs for anti-crisis management. The number of employees involved in the risk management process is also consistent with this conclusion. What is more, the size of the company does not affect the number of external employees involved in the risk management process.

In view of the above, it is advisable for logistics companies to keep a register of corporate risks. Reserchers reasonably note that organizations that develop an adequate risk register will be able to identify immediate supply chain threats associated with their business operations and quickly develop strategies to mitigate such risks before they lead to catastrophic losses over time. Suffice it to say that organizations that develop their risk register will be able to identify the immediate supply chain risks associated with their business operations and thus be able to mitigate such risks before they lead to catastrophic losses, [25,26].

Above all, significant risks lie in particular in globalization and outsourcing. We agree with Urciuoli [27] that outsourcing and globalization can increase the vulnerability of supply chains to unexpected risks or disruptions. Companies may know very little about the local culture or political conditions of the countries they outsource from. The research findings by Zhai and McDermott [28] also indicate the existence of a risk and manifestation of logistical outsourcing in conditions of asymmetric information, as well as the risk and manifestation of logistical outsourcing caused by the social system imperfection. Finally, in accordance with the principles of game theory, it is noted that the signing of an effective contract is necessary to prevent and control the risk of logistics outsourcing; using the institutional arrangement of intermediary organizations to prevent and control the risk of logistics outsourcing caused by information asymmetries, [28]. A similar opinion regarding the risks of outsourcing logistics companies is emphasized authors at work [29]. Let us supose for the sake of argument that businesses escalate questions that are not related to their core area of expertise to companies that are experts in that area. As a result, efforts are being made to improve efficiency and reduce costs. However, if the outsourcing organization does not operate at the proper level of security and coordination, this creates many risks and problems. As a result, this situation has a negative impact on the business and can lead to a wide range of losses in terms of efficiency, productivity, competitiveness and cost advantage.

Researchers likewise hold that logistics enterprises cannot be perceived only as logistics systems, rather we must take into consideration a whole range of external influences. In this regard, they effect the internal environment of the logistics enterprise and the decision-making processes, thus creating interactive links between their own logistics system and the external environment, [30,31].

It is also expedient to pay attention to the specific risks stemimg from the main risks. For example, in present-day logistics the use of Logistics 4.0 concept by logistics enterprises is relevant. However, Kodym et al. [14] point out that automation, digitization and network technologies

require large infrastructure, implementation and maintenance costs. Investing in new technologies occurs with high financial risk as we do not know which processes will be economically viable in the long run and which will not.

Furthermore, logistics enterprise management is associated with international risks. Similarly, Yan et al. [2] share such a perspective on the problem. Understanding international logistics risks is essential for the smooth operation of international trade, systematically studying the causes, responsible parties and possible consequences of international logistics risks. Drawing on the above, the international logistical risk is classified in terms of the consequences caused by the logistical risk, in combination with the influencing factors and types of risk, a scorecard and a model for international logistical risk evaluation are distinguished.

Likewise, risk management strategy is addressed by authors [3]. The scholars hold that is is imperative to develop a strategy, the task of which would be to optimize the use of resources and costs. A risk management strategy is only successful when it is based on the intersection of logistics goals with the corresponding motivation of enterprise's employees to an innovative development.

That being said, one should also take into account the opinion of researchers [7] as regards the difference between traditional logistics risk management and risk management strategy. In fact that the goal of the latter is not only to deliver the right product at the right time at the right time at the lowest cost with the highest level of quality (this is especially true transaction costs, the magnitude of which is difficult to determine in advance), but also the continuous improvement of logistics processes, the allocation of a separate service and paying more attention to all flow processes.

We share the opinion of Bonsón and Bednárová [17] that the identified threat and risks can be mitigated to a reasonable extent. It comes down to how a company should respond to a declared hazard. The first step will be to develop procedures to anticipate changes in the blockchain and accounting standards.

However, according to authors [19], smart contracts can be impressive, although there emerges a certain complexity in their programming. Smart contracts can function as controls, and if poorly designed, they will give way to imperfect business operations. The legitimacy and completeness of transactions may be in question if the company is engaged in off-chain transactions. Off-chain transactions are not involved in the blockchain and it would not present any additional challenge to verify and reconcile such transactions.

We also agree with the findings of researchers that blockchain does an excellent job of eliminating traditional risks that were more focused on subjects; although further use of blockchain will need to consider new types of risks. Risk will be more focused on IT and companies are moving to blockchain as new users will have to adapt their risk management processes. Moreover, the companies that are just getting started with blockchain can become susceptible to new scams, [32,33].

6 Conclusion

The relevance of this study is manifested in the fact that in order to ensure the effective operation of a logistics company in present-day changing global environment, it is imperative to take into account and minimize the risks that may arise within the company. One of the promising technologies that can be useful in the process of minimizing a number of risks, such as the presence of unnecessary intermediaries, disruptions in workflow, security problems, can be blockchain technology, which is capable of preventing errors, illegal labeling of goods, and other fraudulent activities.

During the implementation of blockchain technology in the company's activities, there are a number of possible directions and alternatives for its use, which, in turn, also requires an assessment of the risks of such implementation. The analysis of these risks involves the analysis of possible development alternatives and the choice of the optimal opportunity to evaluate the probability of the selected options' implementation taking into account the presence of uncertainty. Realization of probable risks and effects from the implementation of blockchain technology may be random, therefore quantitative estimates can be obtained using the probability theory framework.

The process of this research included the assessment and comparison of three possible alternatives. As a result of solving the statistical game according to criteria of maximax, Laplace, Wald, Savage, Bayesian, Hurwicz, the A_2 strategy ("the certification of new types of logistics services") was most frequently recommended. This means that the use of blockchain technology to certify new activities will be applied with relatively less economic risk for the studied logistics companies.

It is expedient for further research to integrate blockchain technology with state-of-the-art ERP systems of logistics companies in the further context of elaborating the concept of Logistics 4.0.

6.1 Limitations

The limitation of the study was that the timeframe is based on information as of 2022. The number of respondents was three companies, with geographical restrictions determined by the fact that the companies surveyed belonged to the country of Azerbaijan.

6.2 Originality

The study solved a number of scientific tasks. In particular, an algorithm for analysing corporate governance risks when using blockchain technologies in the activities of logistics companies when concluding smart contracts, certifying new types of transportation, and integrating cryptocurrency for delivery payments is developed. Proposals for improving the corporate risk management of logistics companies have been supplemented.

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Roadmap to achieve operational excellence through Lean Management implementation and quality management system conformance
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Roadmap to achieve operational excellence through Lean Management implementation and quality management system conformance

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Abstract: Automotive companies are facing major challenges, namely competitiveness and the evolution that characterizes the sector. To ensure their sustainability, companies operating in the automotive industry are concentrating their efforts on reducing waste sources throughout the supply chain by implementing a variety of Lean Management tools. The compliance of the quality management system with the requirements of the international automotive standard IATF 16949:2016 is also a top priority for automotive suppliers. IATF certification is required to operate in the automotive market and enables organizations to meet customer requirements and demonstrate the quality assurance of their systems. This paper analyzes the principles of the Lean Management organizational tools in correlation with the requirements of the IATF automotive standard and determines their synergistic impact on operational excellence. Based on the correlation analysis performed, an original roadmap that will serve as a guide for automotive companies has been developed. The findings show that in order to achieve operational excellence, it is necessary to implement the five Lean Management organizational tools in correlation with the operational requirements dictated in chapter 8 as well as the leadership requirements outlined in chapter 5 of the international automotive standard.

1 Introduction

Faced with the competitiveness and dynamic development of the sector, automotive manufacturing companies aim to optimize the quality of the manufactured products, increase customer satisfaction and improve the overall performance of their systems. Controlling supply chain flows and operations, improving results, and ensuring the effectiveness of quality management systems (QMS) are among the major challenges faced by automotive companies.

Nowadays, Lean Management is one of the most discussed concepts in the literature and the most implemented in industrial environments. Lean Management is based on a set of principles and tools whose objective is to eliminate wastes, optimize flows and improve the efficiency and performance of organizations while involving personnel and creating teamwork spirit [1-4]. Adopted by operational processes within manufacturing companies, Lean Manufacturing eliminates non-value-added activities caused by overproduction, inventory, waiting time, motion, transportation, defects and errors, over-processing and non-utilized talent [5-10].

IATF 16949:2016 is the international automotive quality management system standard intended for automotive companies [11-13]. Through its requirements, the IATF standard promotes continuous improvement and involves automotive organizations in preventing defects and errors as well as reducing wastes and variations in the supply chain [11,14]. The requirements related to management's commitment are defined in the chapter "5: leadership", the resources management is detailed in the chapter "7: support", the operational requirements are defined in the chapter "8: Operation", the evaluation methods are determined in the chapter "9: performance evaluation" and the requirements for improvement are specified in the chapter "10: improvement" [11,15,16].

Operational Excellence (OE) is a systematic approach that encompasses a set of methods enabling organizations to perfect their performance and achieve sustainable results [17-20]. The principles of OE are classified into four categories: "Culture", "Continuous improvement", "Enterprise Alignment" and "Results" [17,18]. The "culture" dimension emphasizes leadership, human resources management and motivation, teamwork spirit and the improvement of working conditions. "Continuous improvement" concerns the improvement of processes, quality assurance and the elimination of wastes. "Enterprise alignment" assesses the organization's vision, policy, and strategy. The "Results" dimension concerns the monitoring of performance indicators and the evaluation of customer satisfaction [18].

Given the diversity of Lean Management tools and the variety of IATF requirements, several automotive companies wishing to reach operational excellence while ensuring the quality assurance of their systems and avoiding wastes in the supply chain are unaware of the approach to follow. In the literature, it was found that no study has investigated Lean Management in correlation with automotive standard requirements and Operational excellence. In this context, this paper aims to demonstrate to automotive companies the impact of the implementation of Lean Management organizational tools in correlation with the requirements of the IATF 16949: 2016 automotive standard on operational excellence. A roadmap, which determines the Lean Management tools to be implemented as priority and the relevant IATF clauses to focus on, has been developed to guide automotive companies in establishing their improvement plan in order to achieve operational excellence.

2 Categorization of Lean Management tools

Lean Management is based on several methods, techniques and tools that are differentiated by their concept, rules and operation mode. Lean Management tools can be divided into four categories:

- Analytical tools: value Stream mapping (VSM) and bottleneck analysis. VSM is a method for mapping material and information flow and identifying the different sources of wastes [5,8,21]. Bottleneck analysis is a technique for production balancing that aims to respond to customer demand [8].
- Operational tools process-focused: Poka Yoke, Kaizen, Smed and Jidoka. The poka yoke is an Error-proofing device to prevent defects and errors [5,22]. Kaizen is based on small steps of continuous improvement performed within short periods of time [5]. SMED enables the optimization of changeover times [23]. Jidoka is a visual warning tool for non-conformity detection [5].
- Operational tools flow-focused: Just-In-Time (JIT) and KANBAN. These tools aim to optimize flows and storage areas in order to meet customer delivery requirements [21,24].
- Organizational tools: 5S, standardized work, Visual management, Total Productive Maintenance (TPM) and Total Quality Management (TQM). 5S enables organizations to take the first step towards continuous improvement. Standardized work is fundamental for operational activities' organization [25]. Visual management supports managers in decision-making [21]. TPM improves the effectiveness and efficiency of business processes [26]. TQM improves the QMS and minimizes defects and errors [27,28].

Lean Management analytical tools and operational tools process-focused and flow-focused enable the organizations to improve their workshops and business processes. Organizational tools enable the improvement all of the company's levels and processes, including management, operational and support processes. Several studies have shown that Lean Management excels in the automotive industry due to high customer demand, high level of competitiveness and customer-specific requirements [6,21,29-31]. In this study, Lean Management organizational tools are considered.

3 The steps of the roadmap's development

The present paper analyzes the impact of the adoption of each Lean Management organizational tool and the compliance of QMS with IATF 16949:2016 requirements on operational excellence. For this purpose, the preselected Lean Management tools were analyzed in correlation with the analysis of the IATF standard requirements. Then, factors and key performance indicators (KPIs) that are positively influenced by the adoption of each tool and the implementation of the relevant IATF requirement were determined and finally, the link between these KPIs/factors and the OE dimensions is established. The considered KPIs were determined according to IATF standard. In the context of quality assurance and customer satisfaction monitoring, IATF 16949:2016 requires organizations to assess internal and external performance. A list of indicators is proposed by the automotive standard in clause 9.1.2.1, which should be completed by each organization according to its activity, QMS content, customer requirements and the complexity of the manufacturing processes. KPIs list include delivered part quality performance, delivery performance, customer disruptions and warranties [11]. Additionally, the IATF automotive standard requires conducting a management review in order to assess the consistency of the QMS with the strategy established by the organization as well as the effectiveness of the QMS and the improvement opportunities to be seized. Management review inputs are defined in clause 9.3.2.1 of the automotive standard. The required KPIs in relation to the operational aspect are: cost of internal and external poor quality, process effectiveness, process efficiency, product conformance, customer satisfaction, maintenance performance, warranty performance and finally actual field failures [11]. Table 1 summarizes the list of internal and external KPIs considered in this article. Internal KPIs concern the organization's internal performance, while external KPIs monitor customer satisfaction.

Based on the correlation analysis performed, a roadmap has been developed in the second section of the present paper. Automotive companies can refer to the roadmap and identify QMS suggested improvements, Lean Management tools and techniques to prioritize, as well as IATF requirements that companies should focus on in order to achieve operational excellence.

Table 1 Determination of internal and external KPIs according to the IATF 16949:2016 standard

KPI type	KPI label
Internal KPI	- Cost of internal poor quality - Process effectiveness - Process efficiency - Product conformance - Maintenance performance
External KPI	- Delivered part quality performance - Delivery performance - Customer disruptions - Warranty - Cost of external poor quality

4 Result and discussion

4.1 Correlation analysis between Lean Management organizational tools and IATF requirements and determination of their impact on operational excellence

The objective of Lean Management is to eliminate wastes, optimize material and information flow, increase customer satisfaction and produce at the best quality-cost-time ratio. This is in alliance with clause 10.3.1 of the international automotive standard, which requires organizations to define a continuous improvement process in order to reduce wastes [11,14]. In this section, the preselected Lean Management tools are analyzed in correlation with the requirements contained in the IATF 16949:2016 standard. Table 2 summarizes this analysis and presents the impact of the implementation of Lean Management organizational tools and the compliance of QMS with the automotive standard requirements on the OE dimensions.

"5S" principle can be linked to clauses 7.1.4.1 and 8.5.4.1 of the IATF 16949:2016 standard. Clause 7.1.4.1 requires organizations to maintain the environment for the operation of processes in a state of order while complying with applicable cleanliness and maintenance requirements [11]. The compliance of the QMS with this requirement and the adoption of the 5S tool enable reduction of industrial accident risks, improve the execution of operational activities, participate in the quality assurance approach and increase productivity, manpower effectiveness and efficiency. Clause 8.5.4.1 requires automotive companies to preserve products' quality throughout the supply chain [11]. The implementation of the 5S tool enables organizations to conform their QMS to this IATF requirement and to ensure the quality of the delivered products by meeting customer requirements. Preserving product quality reduces the internal rejection rate, costs related to reworks and repairs, and the number of customer complaints.

"Standardized work" principle is linked to clause 8.5.1.2 of the IATF 16949:2016 standard, which requires organizations to establish standardized work instructions, including workstation safety rules and to ensure that instructions are communicated to the concerned personnel [11]. Standardized work enables organizations to reduce industrial accident risks and produce on time, parts at the required quality level. Productivity, delivery time, rejection rate and manpower efficiency and effectiveness are all improved when the work is standardized.

"Visual management" is linked to clause 5.3.1 of the automotive standard, which involves management in designating the personnel responsible for monitoring customer satisfaction [11]. Customer scorecards are one of the "Visual management" applications. Based on customer scorecard data analysis, the management can improve the organization's policy and strategy and make the right decisions at the right time. By analyzing the collected data from customer portals and implementing corrective actions in case of non-achievement of targets, automotive companies optimize their processes effectiveness and improve their external KPIs.

TPM is explicitly required in the IATF Automotive Standard in clause 8.5.1.5 [11]. Maintenance management is more efficient when the objectives are defined in coherence with the organization's strategy and when the deviations between the monitoring results and the predefined targets are constantly analyzed and corrected. TPM ensures quality at the source and improves internal and external KPIs. Organizations with reliable manufacturing equipment produce in accordance with customer requirements, improve maintenance performance and improve the effectiveness of operational processes. Costs related to corrective maintenance and loss of productivity are minimized when TPM is implemented.

TQM method principles are linked to clauses 5.1.2, 10.2.3, 10.2.4, 10.2.5 and 9.2 of the IATF standard. Clause 5.1.2 requires management's commitment to customer-focused approach [11]. As a leader, the management promotes the employees commitment and supports them in operational management activities. The quality policy, the objectives and the strategy are reviewed by incorporating all the necessary actions to continuously satisfy the customer. A QMS focused on customer satisfaction prompts all processes to improve their operations and ensure the quality of the delivered products. All external KPIs are improved when the organization focuses on meeting customer requirements. Clause 10.2.3 requires organizations to implement a process for problem-solving [11]. The implementation of this clause ensures a good collaborative climate by involving multidisciplinary actors in the process.

Table 2 Synthesis of the correlation analysis between Lean Management organizational tools and IATF requirements and determination of their impact on OE

Lean Management tool	**Related IATF 16949 :2016 clause**	**Impacted factor/KPI**	**Concerned OE dimension**
5S	7.1.4.1 Maintain the premises in a state of order	Working environnement	Culture
		Operational process efficiency and effectiveness	Results
		Quality assurance	Continuous improvement
	8.5.4.1 Product quality preservation	Quality assurance	Continuous improvement
		Delivered part quality performance, Operational process effectiveness, Cost of internal poor quality	Results
Standardized work	8.5.1.2 Standardized work instructions	Working environnement	Culture
		Quality assurance	Continuous improvement
		Delivered part quality performance, Process effectiveness, Operational process efficiency	Results
Visual management	5.3.1 Management involvement in designating the personnel responsible for customer satisfaction monitoring	Strategy and policy	Entreprise alignement
		Process effectiveness, Delivered part quality performance, Delivery performance, Customer disruptions, Warranty, Cost of external poor quality	Results
		Process improvement	Continuous improvement
TPM	8.5.1.5 Implementation of a documented TPM process	Management of maintenance by target	Entreprise alignement
		Quality assurance	Continuous improvement
		Cost of internal poor quality, Process effectiveness, Product conformance, Maintenance performance, Delivered part quality performance, Delivery Performance	Results
TQM	5.1.2 Management's commitment to the customer focus concept	Commitment and Leadership	Culture
		Strategy and policy	Entreprise alignement
		Quality assurance, Process improvement	Continuous improvement
		Delivered part quality performance, Delivery Performance , Customer disruptions, Warranty, Cost of external poor quality	Results
	10.2.3 Problem-solving methodology	Multidisciplinary working group	Culture
		Cost of internal poor quality, Process effectiveness, Operational process efficiency, Product conformance, Maintenance performance, Delivered part quality performance, Delivery performance, Customer disruptions, Warranty, Cost of external poor quality	Results
	10.2.4 Error-proofing devices	Quality assurance	Continuous improvement
		Cost of internal poor quality, Process effectiveness, Product conformance, Delivered part quality performance, Delivery performance, Cost of external poor quality	Results
	10.2.5 Warranty management	Warranty, Cost of external poor quality	Results
	9.2 Internal audits management	Quality assurance, Process improvement	Continuous improvement
		Strategy and policy	Entreprise alignement
		Cost of internal poor quality, Process effectiveness, Operational process efficiency, Product conformance, Maintenance performance, Delivered part quality performance, Delivery performance, Customer disruptions, Warranty, Cost of external poor quality	Results

The analysis of internal and external dysfunctions enables automotive companies to minimize poor quality costs, improve the processes' operations and manpower efficiency, reduce the non-conformity rate and improve the external KPIs. The problem-solving methodology can be used to solve the different processes' dysfunctions and thus contributes to the improvement of their operations. Clause 10.2.4 requires organizations to develop a documented process to manage Error-proofing devices [11]. These devices enable organizations to control the risks of process errors and quality defects and reduce the costs related to scrap, rework, and repairs, as well as the costs related to customer complaints. These devices improve processes' effectiveness by enabling them to achieve quality objectives. Clause 10.2.5 requires automotive companies to develop a warranty management process [11]. This allows organizations to eradicate problems detected by end customers and thus minimize the costs of external poor quality. Clause 9.2 of the IATF Standard requires organizations to conduct QMS audits, product audits and manufacturing process audits [11]. Audits assess the organization's performance and determine the improvement opportunities to be seized. Based on audit deviations, the management reviews the quality objectives, the pre-established strategy and the quality policy. Analyzing deviations and implementing the necessary actions enable automotive organizations to improve their internal and external KPIs.

4.2 Development of a roadmap for automotive companies to achieve operational excellence

In this section, a roadmap intended for automotive companies to achieve operational excellence is developed. This roadmap is based on the results of the first section of the present paper, which focuses on the correlation analysis between Lean Management organizational tools and automotive standard requirements and their impact on operational excellence. OE assessment is the first step of this process; it enables organizations to determine their OE maturity level and identify gaps. After the diagnostic, organizations can refer to the developed roadmap to establish their action plan. The latter would contain the Lean Management tools and the IATF requirements to be implemented as a priority. Once the action plan is implemented and deemed effective, a reassessment is necessary. Figure 1 summarizes the improvement process.

The developed roadmap is presented in figure 2, organizations can refer to it in order to prioritize actions, identify the levers on which they should focus and define their needs for resources and competences. An organization which has noted deviations related to the "culture" dimension should focus on the requirements contained in chapters "5: leadership", "7: support", "8: operation" and "10: improvement" and implement 5S as a priority, standardize the work and adopt TQM methods. The improvement of the "culture" dimension is conditioned by a work environment that promotes the operation of the various processes in good conditions, the establishment of a customer-focused spirit, the standardized work, and finally by the adoption of a problem-solving methodology.

Figure 1 Operational excellence improvement process in automotive companies

In order to achieve OE through the "Continuous improvement" dimension, automotive organizations should implement the five Lean Management organizational tools and conform their QMS to the IATF requirements contained in chapters "5: leadership", "7: support", "8: operation", "9: performance evaluation" and "10: improvement". Particular attention should be given to operational management; organizations should organize their production workshops, preserve the product quality through the supply chain, standardize the activities, implement Error-proofing devices, conduct internal audits and adopt the TPM. The assignment of organizational roles and the management's commitment to a customer-focused approach are essential for this OE dimension. For organizations that have identified gaps related to the "Enterprise Alignment" dimension, their action plan should be based on the requirements related to chapters "5: leadership", "8: operation" and "9: performance evaluation" of IATF standard. Visual management, TQM, and TPM should be implemented as a priority. In order to align the operational work with the organization principles, the management's commitment to customer orientation is fundamental, the roles should be assigned, the TPM adopted and the internal audits conducted and their results exploited.

Finally, automotive companies that have noted gaps related to "Results" dimension should implement the five Lean Management organizational tools. The requirements contained in chapters "5: leadership", "7: support", "8: operation", "9: performance evaluation" and "10: improvement" should be analyzed and considered by the organization during the establishment of the action plan. To improve internal and external results, operational management and management's commitment are fundamental. In addition to the improvement axes of the "Continuous improvement" dimension, the "Results" dimension focuses on the problem-solving methodology and the warranty management.

Figure 2 Roadmap for automotive companies to achieve operational excellence

According to the developed roadmap, the requirements contained in chapters "5: leadership" and "8: operation" are fundamental to improving the four dimensions and achieving OE. In fact, chapter 8 requirements guide automotive companies in the operational management of their workshops and enable them to meet customer requirements. Furthermore, leadership is the cornerstone of any improvement process; a committed leader motivates the employees by developing their skills and potential, which will necessarily contribute to the success of improvement projects and the achievement of operational excellence. Referring to the developed roadmap, results show that "culture", "Continuous improvement" and "Results" dimensions are influenced by the effective implementation of the requirements contained in chapter "7: support". The latter determines the requirements related to human resources management, the improvement of their skills, as well as the process for motivating and empowering them. In fact, as mentioned by the authors [27,32], the human factor is the key element of success;

companies with committed and competent personnel achieve the expected results, succeed in implementing their culture and manage effectively the continuous improvement projects.

5 Conclusions

To follow the evolution of the sector and stand out from competitors, automotive companies put special focus on the control of the value chain, the assurance of their QMS and the results of their performance. The effective implementation of the various Lean Management tools and techniques enables automotive companies to improve their performance and optimize flows and processes by making them more effective and efficient. In this paper, Lean Management organizational tools that are 5S, standardized work, Visual management, Total Productive Maintenance and Total Quality Management were analyzed. Based on the correlation analysis between these tools and the requirements contained in the international automotive standard IATF 16949:2016, a roadmap is developed on which automotive companies can rely on to establish their improvement plan in order to achieve operational excellence. The roadmap determines the Lean Management tools to be prioritized in the lean project implementation as well as the IATF requirements to be integrated into the quality management system and implemented as a priority. The correlation analysis and the developed roadmap are among the original features of the present research. The performed analysis has shown that, to achieve operational excellence, organizations should focus in particular on the requirements contained in chapters "8: operation" and "5: leadership", in addition to the five Lean Management organizational tools. From this perspective, an empirical study is in progress involving local automotive companies in order to validate the results of the present article and determine the synergistic effect of Lean Management and the international automotive standard on operational excellence.

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Combining artificial neural networks and fuzzy analytic network process for holistic sustainable performance evaluation in the Moroccan mining industry
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Keywords: sustainable performance evaluation, Moroccan mining industry, fuzzy analytic network process, artificial neural networks, holistic analysis.
Abstract: This article delves into the evaluation of sustainable performance in the mining industry, employing the Fuzzy Analytic Network Process (FANP) method. It specifically concentrates on examining five pivotal dimensions of sustainable development: economic, social, environmental, operational, and stakeholders. Through the application of the FANP method, a meticulous prioritized ranking is established, not only for these dimensions but also for the specific fields within each of them. This holistic approach provides a comprehensive, well-balanced assessment of sustainable performance, offering a wealth of valuable insights that can guide decision-making processes. Moreover, the method's utility extends beyond the mining sector; it is generalized into a versatile model that can be applied across different industries and research domains. This adaptability is achieved by incorporating a machine learning algorithm, with a primary focus on a multilayer perceptron. This model enables the precise determination of a company's overall multidimensional performance by quantifying various facets of performance, among other considerations. The research presented in this article serves to bridge an existing gap in integrated studies specific to the Moroccan mining industry. It provides actionable insights that can significantly enhance management practices and foster sustainable development, making it a valuable contribution to both the industry and the broader research community.

1 Introduction

The mining industry holds a pivotal role in a country's economic progress; however, it grapples with significant environmental and social issues. In light of this, the evaluation of sustainable performance has become indispensable to ensure responsible and enduring mining practices in Morocco. Despite the growing emphasis on sustainable development within the Moroccan mining sector, there's a noticeable absence of comprehensive studies that simultaneously investigate the five crucial dimensions: economic, environmental, social, operational, and stakeholders [1,2]. This deficiency underscores the necessity for a holistic approach to appraising sustainable performance in this field [3,4].

The current study seeks to bridge this gap by employing the Fuzzy Analytic Network Process (FANP) method to assess the sustainable performance of a company engaged in the Moroccan mining industry. The FANP method allows for the examination of interconnections among various dimensions and quantifies their relative significance, thereby furnishing a more thorough and well-balanced evaluation [5].

Furthermore, this approach is generalized into a versatile model that can be employed across diverse sectors or research areas. This versatility is accomplished through the use of a machine learning algorithm, primarily utilizing a multilayer perceptron. The model empowers the assessment of the company's overall multidimensional performance by quantifying various performance aspects.

This research is substantiated by an up-to-date literature review, which underscores the significance of sustainable development in the mining industry and the imperative for a comprehensive evaluation of sustainable performance. Recent references are cited to highlight the

challenges and concerns related to sustainability in the context of mining.

2 Literature review

The mining industry in Morocco is a significant contributor to the country's economy, and it plays a crucial role in various sectors, including mining of minerals, phosphates, and precious metals [6]. Here is an overview of the mining industry in Morocco:

- Phosphate Mining: Morocco is one of the world's largest producers and exporters of phosphate minerals. The country possesses abundant phosphate reserves, which are essential for fertilizers and agricultural production. Phosphate mining is a major source of revenue for Morocco.
- Precious Metals: Morocco also has a rich history of mining precious metals, particularly gold and silver. The country is home to several mining projects focused on these metals, attracting both domestic and international investment.
- Diverse Mineral Resources: In addition to phosphates and precious metals, Morocco is known to have substantial deposits of other minerals, including lead, zinc, copper, and barite. The mining sector's diversification has the potential to boost economic growth.
- Economic Contribution: The mining industry contributes significantly to Morocco's GDP and provides employment opportunities, both directly and indirectly, in various regions. It is a critical sector for the country's economic development.
- Regulation and Investment: The Moroccan government has implemented policies to attract foreign investment in the mining sector. This includes offering incentives to companies willing to invest in exploration and mining projects.
- Environmental and Social Considerations: As with many mining industries worldwide, there are environmental and social challenges that need to be addressed in Morocco. Sustainable and responsible mining practices are gaining importance, as the industry seeks to balance economic development with environmental conservation and social well-being.
- Infrastructure Development: The development of infrastructure, including transportation networks, ports, and energy supply, is essential for the growth of the mining sector in Morocco. These investments facilitate the export of mined products.
- Export Markets: Morocco exports a significant portion of its mining products to international markets, making it a key player in global mineral markets.
- Research and Innovation: The Moroccan mining industry has also seen advancements in research and technology to improve efficiency and reduce the environmental impact of mining operations.

In here, we find a compelling fusion of artificial neural networks (ANN) and fuzzy analytic network process (FANP) methodologies to address the intricate challenges of sustainability in the mining sector. This innovative approach is underpinned by an expanding awareness of sustainable development [7].

These studies illustrate the potential of ANN and FANP as powerful tools for comprehensive sustainability assessment. By amalgamating ANN's data-driven capabilities and FANP's ability to handle complex decision-making processes, researchers have managed to provide a well-rounded framework for evaluating sustainable performance [8].

Crucially, the literature highlights the unique context of the Moroccan mining industry, where environmental, social, and economic dimensions intertwine. This hybrid approach offers precise insights, paving the way for actionable recommendations that can catalyze responsible practices and contribute to the long-term sustainability of the industry. It is evident from these findings that the combination of ANN and FANP methodologies is becoming increasingly indispensable in the mining sector, serving as a promising blueprint for holistic sustainable performance evaluation in Morocco and potentially in other comparable industries [9].

3 Methodology

This paragraph outlines the methodology adopted in this study, which primarily focuses on assessing the overall multidimensional performance of the mining industry. The Fuzzy Analytic Network Process (FANP) was employed in this research. To carry out the FANP analysis, the SuperDecision software was utilized. By employing FANP through the SuperDecision software, we were able to effectively evaluate the multidimensional performance of the mining industry rigorously and comprehensively. Before proceeding to the next step of generalization, an intermediate method was employed to consolidate the obtained results. This method involved the direct application of the minimal condition algorithm. In this transitional phase, the minimal condition algorithm allowed for the evaluation and verification of the dimensional and overall performance of the utilized approach. It served to confirm the relevance of the obtained results before embarking on the generalization process.

Once the validation of performance levels was completed using the minimal condition algorithm, the method was generalized by employing the multilayer perceptron. This choice was motivated by the multilayer perceptron's ability to handle more complex problems and capture non-linear relationships between variables. By incorporating the multilayer perceptron, the applicability of the method was extended to broader domains, enabling more general conclusions to be drawn from the obtained results.

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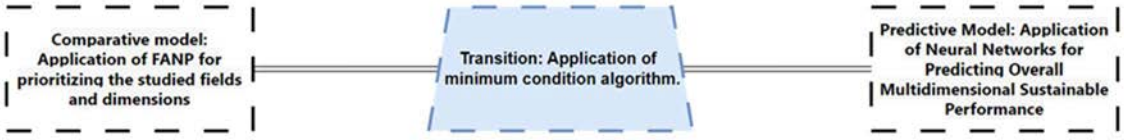


Figure 1 The main phases of the Fuzzy Analytic Network Process

The diagram depicted in Figure 1 provides a detailed representation of the approach followed in this study, starting from the Fuzzy Analytic Network Process (FANP) and extending to machine learning through the minimal condition algorithm. By following this comprehensive approach, from FANP to the minimal condition algorithm and machine learning, the study ensures a rigorous and robust analysis of sustainable performance. The diagram offers a visual representation of the step-by-step methodology adopted, facilitating a clear understanding of the research framework.

3.1 Initiation of the study

This study is mainly based on the application of the Fuzzy Analytic Network Process (FANP) method to the data of one of the largest multinational companies operating in the mining industry in Morocco. The evaluation of the company's performance was conducted using judgments from qualified experts in the field of mining. The experts were selected based on their expertise and in-depth knowledge of the company and the industry. Their judgments were collected and utilized to assess relevant criteria and sub-criteria, thereby quantifying and prioritizing the company's overall performance. This expert judgment-based approach aims to provide an accurate and informed perspective to the evaluation, leveraging the expertise and experience of professionals in the mining sector.

The study is based on the following five dimensions: economic, environmental, social, operational, and stakeholder transparency. These dimensions are considered the main pillars of sustainable development and will serve as the primary evaluation criteria. Each dimension encompasses a set of fields, which in turn will form the sub-criteria for evaluation.

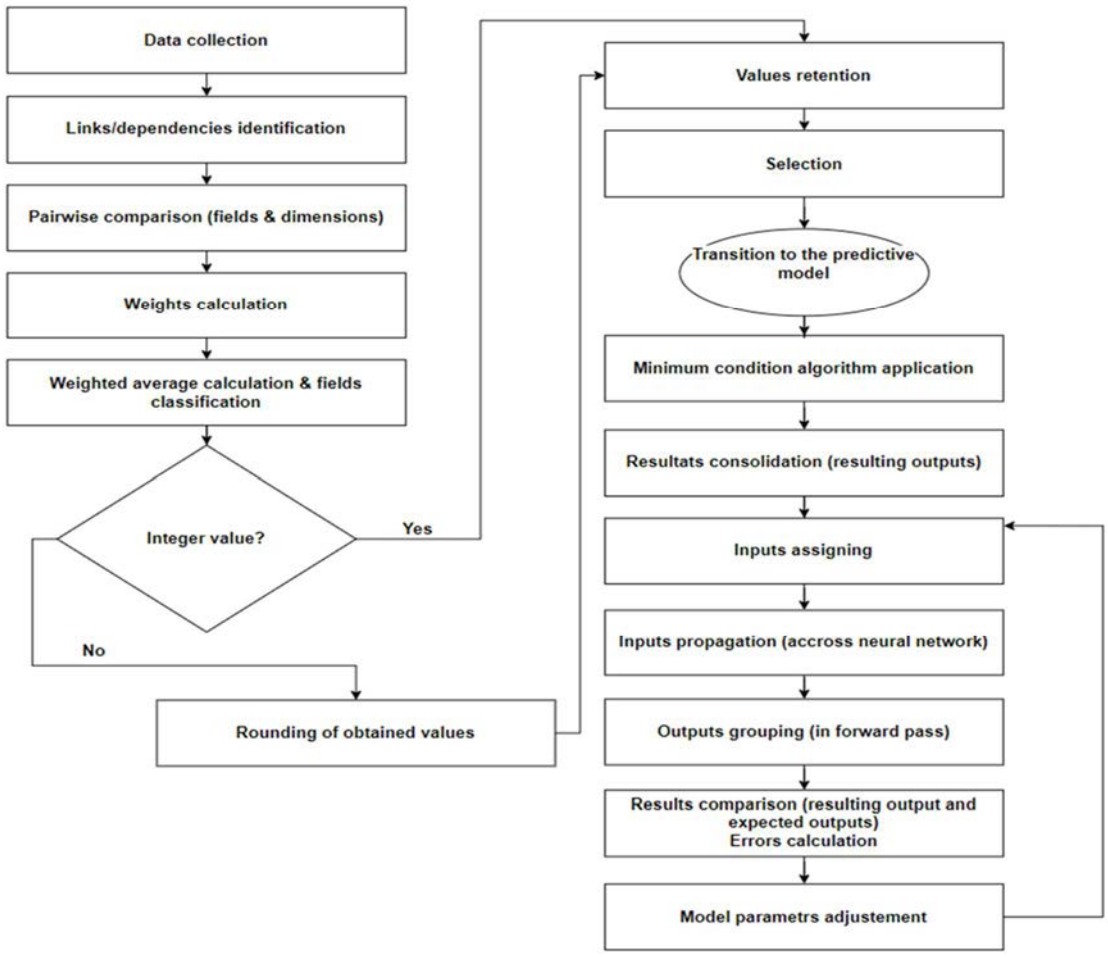


Figure 2 Diagram detailing the followed approach

1- The economic dimension focuses on assessing the mining company's financial performance and economic viability.
2- The environmental dimension aims to evaluate the company's impact on the natural environment and its commitment to sustainable practices.
3- The social dimension examines the company's social responsibility and its contribution to the well-being of local communities and stakeholders.
4- The operational dimension assesses the efficiency and effectiveness of the company's operational processes and practices.
5- The stakeholder transparency dimension focuses on the company's communication and transparency in its interactions with various stakeholders.

Considering these dimensions and their respective fields, a comprehensive evaluation framework is established based on the FANP method, allowing for a holistic assessment of the mining company's sustainable performance. This structured approach ensures that key aspects of sustainable development are adequately addressed and evaluated, providing valuable insights for decision-making and improvement initiatives.

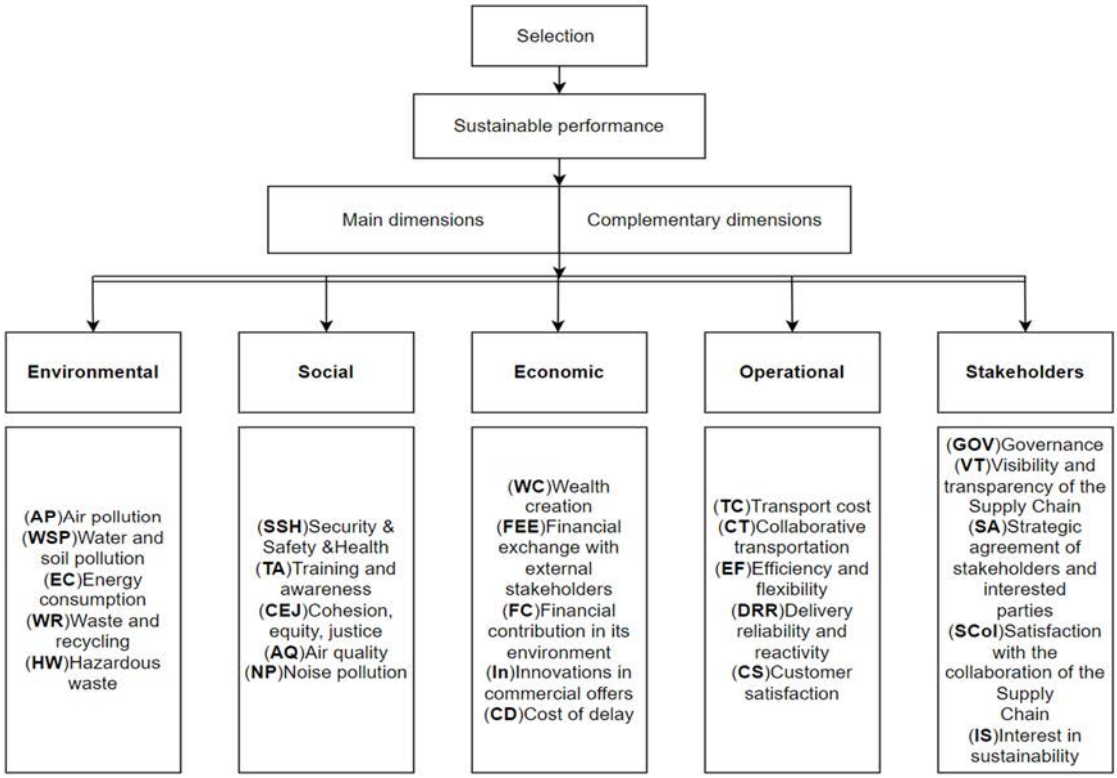


Figure 3 The framework of FANP for sustainable performance assessment

3.2 Means and methods

3.2.1 FANP-based decision-making

The Fuzzy Analytic Network Process (FANP) is a multicriteria decision-making method that effectively addresses complex problems by incorporating both dependency relationships and fuzzy judgments. Introduced by Thomas L. Saaty, 1980 [10], FANP has found widespread application in the fields of operations research and decision science. The FANP methodology revolves around the construction of an analytic network that captures the relationships among criteria, sub-criteria, and alternatives. Pairwise comparisons are conducted to assess the relative weights of network elements [11]. Fuzzy judgments are accommodated using fuzzy logic It connects ANP to fuzzy logic, a valuable technique for dealing with nondeterministic and nonlinear issues. It can represent fuzzy and qualitative knowledge, and so can reason like a human [12], allowing for the modeling of uncertainties and imprecisions within the decision-making process. The FANP method provides quantitative outputs for prioritizing criteria, evaluating performance, and making informed decisions.

3.2.2 Weighted sum and weighted average

Weighted sum and weighted average are two mathematical computations employed to combine a set of values by assigning weights to each value [13]. Although both methods involve the allocation of weights to individual values [14], the selection between the two methods depends on the specific context and the intended purpose of the calculation as they diverge in the manner in which these weighted values are consolidated [15]. In a weighted sum, each value is multiplied by its corresponding weight and subsequently added together [16,17] This yields the aggregate of the weighted values. Mathematically, it can be represented as (1):

$$Weighted\ Sum = (Value1 * Weight1) + (Value2 * Weight2) + \ldots + (ValueN * WeightN) \quad (1)$$

The weighted sum produces a comprehensive value that encompasses the cumulative contribution of each value, accounting for its assigned weight.

While in a weighted average, each value is multiplied by its weight, and the sum of the weighted values is divided by the sum of the weights. Mathematically, it can be expressed as (2):

$$Weighted\ average = \frac{((Value1 * Weight1) + (Value2 * Weight2) + \ldots + (ValueN * WeightN))}{(Weight1 + Weight2 + \ldots + WeightN)} \quad (2)$$

The weighted average generates a representative value that incorporates both the values and their respective weights. This approach is beneficial when calculating an average that acknowledges the importance or significance of each value [15].

3.2.3 Presentation of the "Minimum condition algorithm"

The minimum condition algorithm, as described earlier, is utilized in our performance measurement system to calculate the overall multidimensional sustainable performance value. This algorithm assigns the minimum value of the fields within each dimension to determine the performance level of that dimension. The steps involved in the algorithm can be summarized as Figure 4.

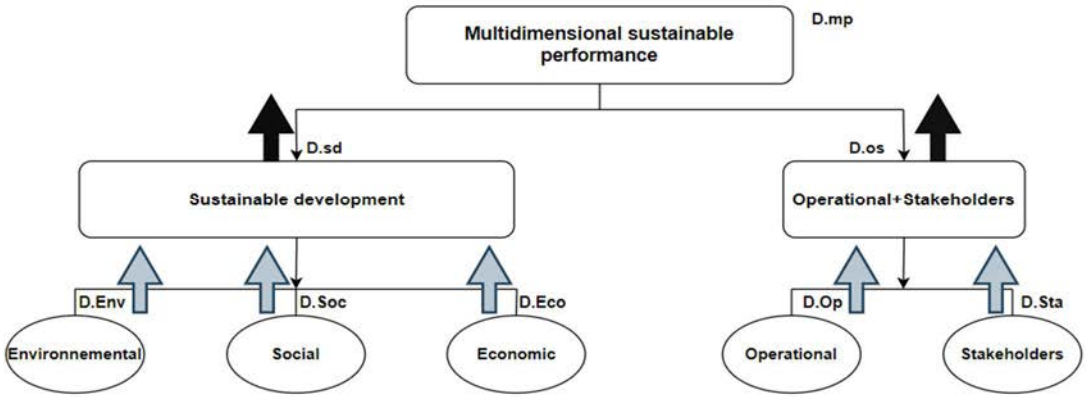


Figure 4 Performance calculation levels

1. Field Performance Determination: Assign a score ranging from 1 to 9 to each field within every dimension.
2. Dimension Scoring: Determine the score for each dimension by considering the minimum scores of the fields within that dimension. The performance of the dimension is equivalent to the minimum value among its fields.
3. Comparison of Dimensional Performance:
4. Sustainable Development Performance (D.sd): Determine the minimum dimensional performance value among economic, environmental, and social dimensions. D.sd = Min (economic dimensional performance, environmental dimensional performance, social dimensional performance)
5. Operational Performance + Stakeholders (D.os): Determine the minimum dimensional performance value among operational and stakeholder dimensions. D.os = Min (operational dimensional performance, stakeholder dimensional performance).
6. Performance Level Determination for D.sd and D.os.
7. Calculation of Sustainable Multidimensional Performance (D.mp): D.mp = Min performance level (D.sd, D.os).

The output values are derived directly from the application of the minimum condition algorithm, which assumes that a global performance level (output) is only achieved when all the inputs are validated.

The minimum condition algorithm comprises three main performance levels, adopting a scale from 1 to 9. Consequently, the output performance level is determined by the lowest score assigned to the dimensions as mentioned in Figure 5.

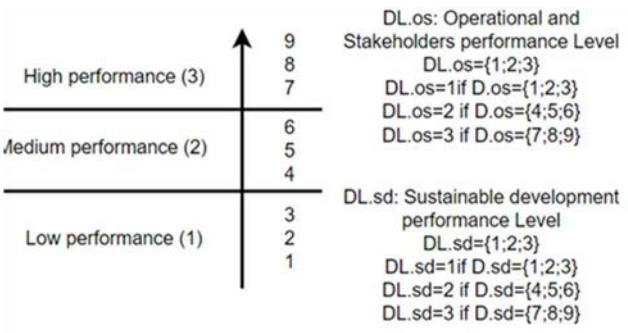


Figure 5 Multidimensional performance measurement scale

3.2.4 Artificial neural network

ANN is a data processing archetype that is triggered in such a way that the information in the human brain is processed by a biological nervous system. It is made up of a large number of highly interconnected processing components, which are neurons that work together to solve certain issues. For chores requiring precise and rapid mathematical calculations, the computer surpasses organic brain systems. Artificial neural systems ensure the production of innovative information processing networks. Its computation falls somewhere in the middle between artificial intelligence and engineering [18].

Neural networks, specifically multilayer perceptron's, are a branch of artificial intelligence that model non-linear mappings. They consist of interconnected nodes with weighted connections and non-linear activation functions. By combining these functions, they approximate complex relationships [19]. Used in many fields, the application of ANNs has seen a lot of success in a number of different areas of specialization, including.

The multilayer perceptron is a feed-forward network with multiple layers, where the input layer serves as a conduit for data transmission.

4 Practical case

4.1 Application FANP

In this case study, experts utilized the Fuzzy Analytic Network Process (FANP) with the assistance of the user-friendly SuperDecisions software [20,21].

software integrates advanced methodologies to enhance decision-making processes across different domains [22]. Through pairwise comparisons, a group of carefully selected experts with expertise in sustainable performance assessment identified the interactions between various dimensions and fields. These interactions shed light on the intricate relationships within the evaluated system. Notably, direct interactions among the fields specified in the provided table were identified by the experts [23].

The SuperDecisions software visually presents the interactions through a model represented in Figure 6. The model consists of five clusters, each representing a specific dimension. Within each cluster, nodes are assigned to represent the fields under study. This visual representation provides a clear and organized depiction of the relationships between dimensions and the specific fields being assessed. The clustering structure facilitates the categorization and grouping of interconnected fields, enabling a comprehensive analysis of the entire system.

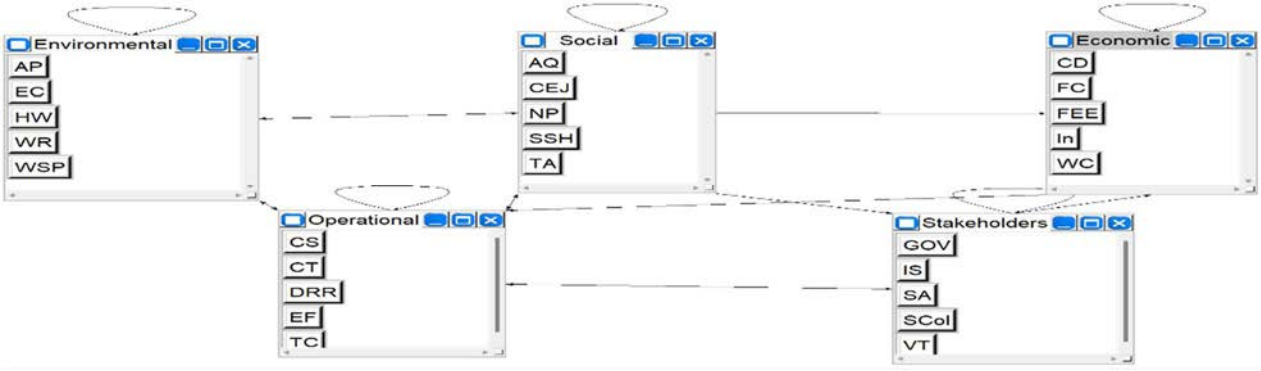


Figure 6 Selection network

In FANP evaluation, values 1, 3, 5, 7, and 9 (Table 1) are frequently employed to convey the degrees of importance or preference for criteria or alternatives. These values are linked with descriptive language to aid in the quantification of decision-makers uncertain or imprecise judgments. Here is a general interpretation of the typical connotations associated with these values which has been used in pairwise comparison.

Table 1 Pairwise evaluation scale

Importance	Explanation
1	Signifies minimal importance or extremely low preference. This implies that the criterion is deemed insignificantly important or inferior when compared to the majority of other criteria.
3	Represents moderate importance or moderate preference. This suggests that the criterion holds a certain level of significance or a moderately preferred position among the other criteria.
5	Indicates an intermediate level of importance or a neutral preference. This means that the criterion is considered to possess a medium degree of importance or a neutral preference when compared to other criteria.
7	Denotes a high level of importance or a strong preference. This indicates that the criterion is regarded as having substantial importance or a significantly higher preference relative to the other criteria.
9	Reflects an extremely high level of importance or preference. This signifies that the criterion is viewed as critically important or holds an exceptionally high preference when compared to other criteria.
2,4,6,8	Even scores reflect intermediate values.

Combining artificial neural networks and fuzzy analytic network process for holistic sustainable performance evaluation in the Moroccan mining industry

Farchi Chayma, Touzi Badr, Farchi Fadwa, Mousrij Ahmed

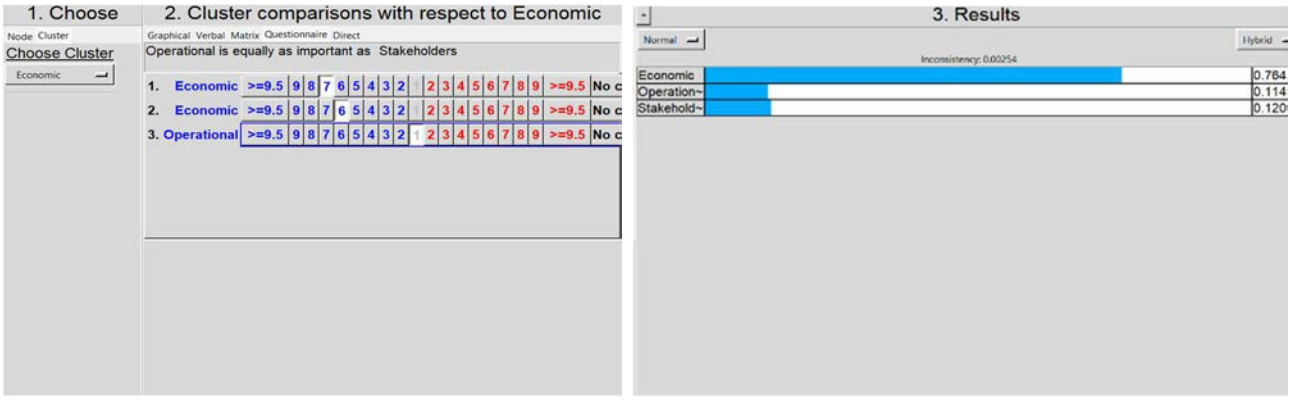


Figure 7 Pairwise comparison example

a- Dimensions and fields prioritization

The Fuzzy Analytic Network Process (FANP) is utilized in this study to prioritize fields by assigning weights. The primary goal is to quantify and rank the elements involved in the decision-making process, allowing for a more informed approach. Weight prioritization becomes crucial when multiple criteria are considered, as it helps identify the most impactful or relevant ones. By doing so, it enables a focus on the key aspects and prevents subjective or equal evaluation of all criteria.

Once the analytic network is constructed to represent the relationships between criteria and sub-criteria (or dimensions and fields), causal links are established, either as cause-effect or dependency connections. These links capture the associations between dimensions and fields, to which weights are assigned based on their significance. This assignment is done through pairwise comparison analysis, where two criteria are compared at a time to determine their relative importance compared to others. The resulting weights are then used to calculate weighted weights for each criterion and sub-criterion associated with the dimensions. These weighted weights indicate the relative importance of each criterion within the context of sustainability being studied. The Figure 8 below visually represents the relative importance (weights) of sub-criteria and main criteria based on the pairwise comparisons conducted.

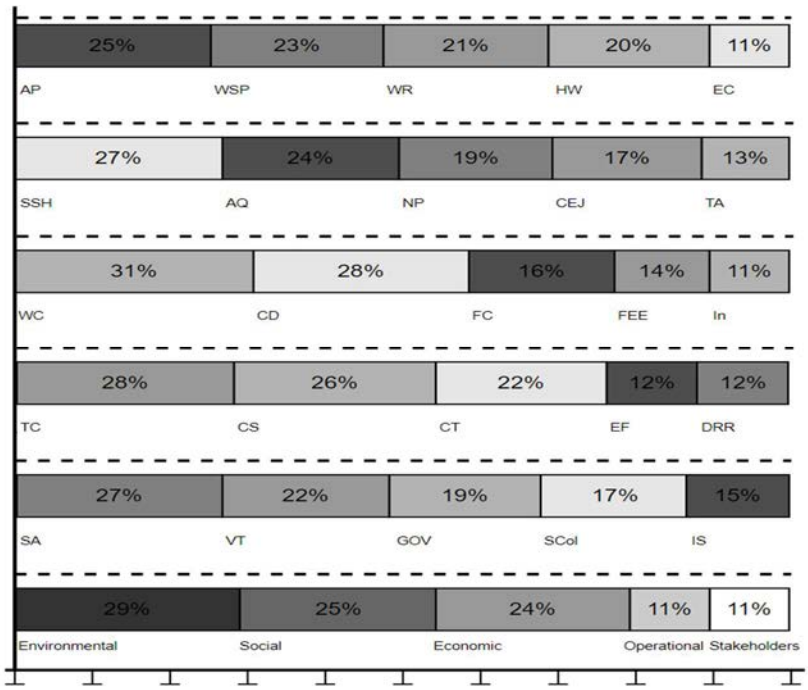


Figure 8 The relative importance (weights) for main criteria and sub-criteria

b- Sustainable performance calculation

By applying weighted weights [24], the calculation of sustainable performance involves aggregating the measurements of criteria and sub-criteria linked to each dimension. This computation can be accomplished through techniques like the weighted sum or weighted average of scores. The weighted average is particularly valuable as it provides a consolidated metric that considers the relative

distribution of weights by dividing the weighted sum by the sum of weights (Table 2). In this approach, the weighted average is utilized to determine the sustainable performance of dimensions. By incorporating the weighted weights, it becomes possible to calculate sustainable performance by amalgamating the measurements of criteria.

Table 2 Example of weighted average results

Dimensions	Fields	Weights	Fields performances	Weighted weights	Weighted average
Environmental	AP	0.25	5	1.25	4.37
	WSP	0.23	4	0.92	
	WR	0.21	5	1.05	
	HW	0.20	3	0.6	
	EC	0.11	5	0.55	
Social	SSH	0.27	5	1.35	4.14
	AQ	0.24	4	0.96	
	NP	0.19	4	0.76	
	CEJ	0.17	4	0.68	
	TA	0.13	3	0.39	
Economic	WC	0.31	5	1.55	4.89
	CD	0.28	5	1.4	
	FC	0.16	5	0.8	
	FEE	0.14	5	0.7	
	In	0.11	4	0.44	
Operational	TC	0.28	3	0.84	3.68
	CS	0.26	5	1.3	
	CT	0.22	4	0.88	
	EF	0.12	4	0.48	
	DRR	0.12	4	0.18	
Stakeholders	SA	0.27	5	1.35	4.53
	VT	0.22	5	1.1	
	GOV	0.19	5	0.95	
	SCol	0.17	4	0.68	
	IS	0.15	3	0.45	

Through the utilization of the weighted average, we were able to perform calculations that yielded weighted aggregates. These aggregates served as valuable indicators of the relative performances exhibited by the fields under consideration in this evaluation. The weighted average method takes into account the assigned weights of each field and combines them with their respective performance measures. This approach allows for a comprehensive assessment that considers the varying degrees of importance assigned to each field. By obtaining these weighted aggregates, we gain a deeper understanding of how the different fields compare in terms of their performance within the evaluated context.

4.2 Minimal condition algorithm and artificial neural network

Before proceeding to the next steps, we performed rounding of the weighted scores [24]. Different methods are used to round real values to integers in sustainable performance measurement. In this context, we will adopt the classical approach of rounding the weighted scores. This method involves rounding the real values to the nearest integer using conventional rounding rules, such as rounding up or rounding down.

According to the minimum condition algorithm, the performance level of a higher-level (D.sd, D.os, or D.mp) relies primarily on the minimum performance value among the dimensions (D.Eco, D.Soc, D.Env, D.Op, and D.Sta) contained within that same level or the oversize level being studied (D.os, D.sd). By applying this algorithm, we quantified the performances of D.sd and D.op, and based on these two measures, calculated the overall multidimensional sustainable performance, D.mp.

The resulting data underwent analysis using a machine learning algorithm to investigate the relationship between the various sustainable performance values of the dimensions and the overall sustainable performance value for each scenario. This learning process was carried out using a neural network, specifically a multilayer perceptron, with a database comprising over 200,000 observations from the mining company's performance indicator monitoring systems.

The Table 3 below provides an example of scenarios illustrating the transition from the rounded weighted average to the value of D.mp.

Table 3 Scenarios' examples

Scenario 1			Scenario 2			Scenario 3			Scenario 4		
D.Env= 8	D.sd=2	D.mp=2	D.Env= 8	D.sd=3	D.mp=3	D.Env= 8	D.sd=2	D.mp=2	D.Env= 9	D.sd=3	D.mp=3
D. Soc= 9			D. Soc= 9			D. Soc=			D. Soc= 9		
D.Eco=6			D.Eco=7			D. .Eco=8			D.Eco=9		
D.Op=8	D.os=2		D.Op=8	D.os=3		D.Op=8	D.os=3		D.Op=9	D.os=3	
D.Sta=6			D.Sta=8			D.Sta=8			D.Sta=9		

The elements found in the initial columns of each scenario correspond to the inputs of the ANN model, whereas the elements in the final columns represent the outputs of the model. This structure is designed to capture the relationship between the input variables and the resulting predictions or outcomes generated by the ANN model. The input variables, located in the first columns, serve as the initial information provided to the model, while the output variables, located in the final columns, represent the model's predicted or calculated values based on the given inputs.

4.3 Outcomes of the contribution

The article makes two significant contributions. First, it introduces a method for prioritizing dimensions by assigning weights to them and their respective fields based on their relative impact on overall performance assessment. This approach underscores the substantial influence of the environmental aspect among the various dimensions, underscoring its pivotal role in determining sustainable performance. Dimension prioritization enhances our understanding of the relative significance of different factors in the evaluation of overall performance.

Secondly, the article presents a predictive model employing an Artificial Neural Network (ANN). This model achieves an impressive accuracy rate of 94% with minimal error margins, as evidenced by a negligible Root Mean Square Error (RMSE). By training on the weighted calculations, the ANN model learns the intricate relationships between dimensions, fields, and overall performance, enabling it to provide highly accurate predictions.

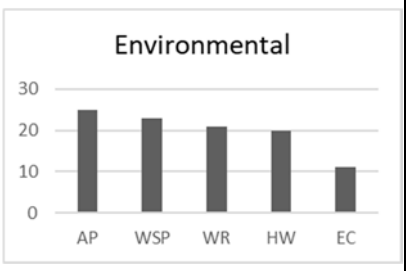
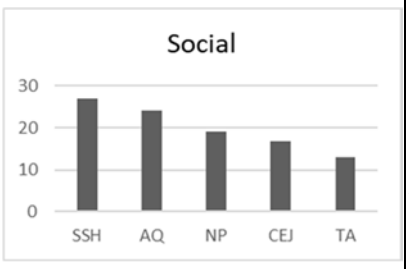
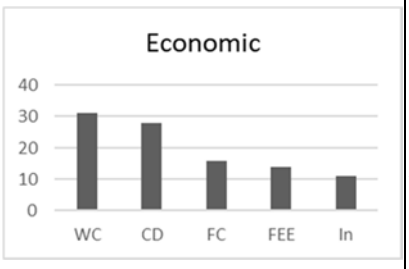
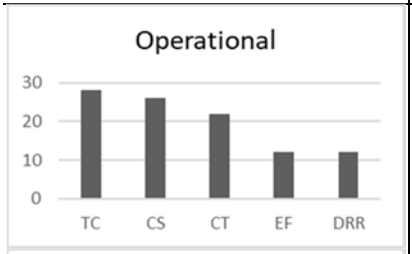
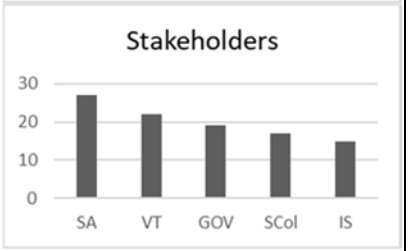
The integration of dimension prioritization and the ANN-based prediction model in this combined approach offers an innovative and efficient method for assessing and predicting multidimensional performance. It not only enhances our comprehension and measurement of sustainable performance in practical applications but also supports decision-making processes and advances progress toward sustainability objectives.

5 Discussion of results

The prioritization of weights assigned to individual fields within the dimensions during the assessment of sustainable performance within a Moroccan mining industry company has emerged as a pivotal step in this endeavor. This weight assignment process has not only facilitated the quantification and ranking of the dimensions and their respective fields but has also yielded a wealth of invaluable insights concerning their relative importance. These insights, in turn, serve as guiding beacons for driving improvement initiatives and informing crucial decision-making processes.

The allocation of weights to fields within each dimension has been transformative in the evaluation process, offering a profound and comprehensive understanding of the intricate web of their relative significance within the broader framework of sustainable performance. It provides stakeholders with a nuanced map, illuminating the areas that exert the most substantial influence on the overarching performance landscape. This, in essence, empowers stakeholders to channel their attention and allocate resources judiciously, concentrating their efforts where they can make the most significant impact on the company's overall sustainable performance. It not only refines the focus but also underscores the power of data-driven decision-making in the pursuit of sustainability goals within the Moroccan mining industry.

Table 4 Relative comparison

Dimensions	Descriptions
	Issues related to air, water, and soil pollution often have significant consequences for the environment. The mining industry can generate emissions of air pollutants, discharge contaminated wastewater, and produce solid waste that can negatively impact surrounding ecosystems. Therefore, in the evaluation of sustainable performance, greater importance may be placed on these dimensions to ensure proper management of environmental impacts. Waste management and recycling are crucial issues in the mining industry. Waste can contain toxic or hazardous substances that require proper management to prevent negative impacts on human health and the environment. Regarding energy consumption, the mining industry is often energy-intensive, requiring a significant amount of energy for mineral extraction, processing, and transportation. Reducing energy consumption can contribute to a more sustainable performance by lowering greenhouse gas emissions and minimizing the company's carbon footprint.
	The higher importance given to SSH and AQ among these fields in the social dimension of sustainable development can be explained by several factors. Firstly, SSH is a major concern in many industries, including the mining industry, as it relates to worker safety, prevention of accidents and occupational illnesses, and adherence to health and hygiene standards. These aspects are essential for ensuring a safe and healthy work environment, as well as protecting the lives and well-being of employees. Similarly, AQ plays a crucial role in sustainable development as air quality directly impacts human health and the environment. The mining industry can generate air emissions such as fine particles and pollutants that have detrimental effects on air quality. Therefore, placing high importance on monitoring and improving air quality contributes to the protection of the health of surrounding communities and the preservation of the environment.
	Overall, the high importance given to WC and CD underscores the significance of wealth creation and cost management in driving economic sustainability and long-term success for mining industry companies. WC reflects here the fundamental objective of the businesses, which is to generate wealth and economic value. It encompasses various aspects such as revenue generation, profitability, and economic growth. Prioritizing WC indicates the emphasis placed on maximizing financial performance and ensuring sustainable economic development. The CD is another critical field as it directly affects the financial aspects of a company. The cost of delay refers to the potential losses or negative consequences that may arise from delays in project execution. Managing and minimizing the cost of delay is crucial for maintaining efficiency, competitiveness, and financial success. By prioritizing CD, companies aim to optimize their resource allocation, mitigate risks, and enhance their overall economic performance.
 	By emphasizing TC and SA, the evaluation of sustainable performance acknowledges the importance of efficient transport cost management, which contributes to operational efficiency, cost reduction, and enhanced competitiveness of the company. Additionally, strategic collaboration with stakeholders ensures a harmonious relationship, social acceptance, and sustainable management of mining projects. This focus aims to achieve optimal operational performance and sustainable development in the mining industry.

The Table 4 above represents the prioritization of fields detailing the dimensions in the evaluation of sustainable performance for a Moroccan mining industry company. The fields are depicted in descending order of their relative importance. This ranking provides a visual representation of the significance of each field in contributing to overall performance.

Furthermore, the results demonstrate a strong and consistent performance of the predictive model, making it a reliable framework for calculating and quantifying multidimensional performance. These findings attest to the model's ability to provide accurate and dependable predictions, rendering it applicable to a wide range of studies, domains, and sectors. With its adaptive nature, the model can be adjusted and customized to fit specific contexts using appropriate performance indicators.

The adaptability of the model allows for its application to diverse case studies, offering increased flexibility and relevance in evaluating multidimensional performance. For instance, in the mining industry, performance indicators such as waste management, energy efficiency, and carbon footprint can be incorporated into the model to assess the sustainability of mining operations.

By utilizing the adaptive predictive model, practitioners and researchers can benefit from a valuable tool for evaluating, comparing, and enhancing multidimensional performance across various contexts. This enables a more personalized and targeted approach, promoting better management of sustainable performance and informed decision-making in diverse industrial sectors and fields of study.

6 Conclusion

The mining industry in Morocco is not only a major contributor to the national economy but also a key global player in the extraction of minerals, phosphates, and precious metals. Its influence reaches across various sectors, and as the industry evolves, it places increasing importance on sustainable and responsible mining practices. The government's support, investment in infrastructure, and commitment to innovation ensure that Morocco remains at the forefront of the global mining landscape.

In this paper, we have focused on this topic in order to study it closely and make decisions based on the results obtained.

In summary, the application of the Fuzzy Analytic Network Process (FANP) method has proven to be highly effective in our study, enabling us to systematically rank and prioritize the five dimensions of sustainable development we examined. The order of priority, as determined by our analysis, is as follows: environmental (29%), social (25%), economic (24%), operational, and stakeholders (11%). This prioritization is a valuable outcome, shedding light on the relative significance of each dimension within the framework of evaluating sustainable performance in the Moroccan mining industry.

Furthermore, our study delved deeper by pinpointing specific subcategories or fields within each dimension, offering a comprehensive understanding of areas that require targeted attention and improvement. By quantifying and highlighting the relative importance of these individual fields, stakeholders and decision-makers are equipped with a clear roadmap, allowing them to channel their efforts towards addressing the most critical aspects of sustainable performance.

Additionally, we calculated the dimensional performance aggregates by employing weighted averages, duly considering the significance assigned to each dimension. This approach permits a thorough assessment of the overall sustainable performance, incorporating the varying degrees of importance assigned to each dimension. It offers a holistic perspective on the company's sustainable performance, taking into account the nuanced interplay between three dimensions.

Moreover, the predictive model we have developed presents a direct and easily interpretable means of estimating the overall performance value, delivering a generalized gauge of the company's performance level. This predictive tool facilitates quick and informed decision-making and is instrumental in providing a snapshot of the company's performance.

The implications of these results and findings are substantial, offering a robust framework for decision-making and improvement initiatives within the Moroccan mining industry. By paying attention to the priority dimensions and specific fields we've identified, companies are well-positioned to elevate their sustainable performance, advocate responsible practices, and make significant contributions to the long-term sustainability of the environment, society, and the economy.

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Implementation of cloud computing in the digital accounting system of logistics companies
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Implementation of cloud computing in the digital accounting system of logistics companies

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Keywords: cloud storage, cloud services, computing, logistics companies, digital accounting.
Abstract: The aim of the article is to determine the capabilities of cloud services for meeting the needs of logistics companies in the management of supply chains and digital accounting. The study provides a review of current academic publications, analysis of official documentation of cloud service provider companies, and expert opinion of the authors of the study. The study was based on information about the 5 most popular cloud services used by companies to perform mathematical calculations. Amazon Web Services focus on reliability and scalability, providing a wide range of data storage and processing services, as well as performing serverless mathematical calculations. Microsoft Azure stands out for its integrated solutions, as well as data management and analytics services. Google Cloud offers a wide range of development and analytics tools, including data visualization and data sharing. Oracle Cloud provides comprehensive financial and database management solutions. SAP Cloud Platform specializes in financial management and analytics solutions. The results of the research open up prospects for studying the problems of integrating services built on different platforms and finding optimal solutions for combining the existing system of mathematical calculations in a logistics company with the offered cloud-based services.

1 Introduction

Digitalization of business life transforms the usual approaches to business. It has become the main trend of business transformation during the coronavirus pandemic, and the activities of logistics companies underwent drastic changes. As personal contact between people was limited, the introduction of digital technologies ensured conducting operations and functioning of business processes. In this aspect, the use of cloud computing has become decisive for ensuring the functioning of logistics companies. However, cloud technologies not only solved the problem of complying with pandemic restrictions, they also opened up new opportunities in the use of information about business processes, in particular, performing mathematical calculations and managing this information. The accounting system of logistics companies that use cloud technologies can reach a higher level of providing management information needs.

The advantage of cloud computing is the ability to use remote servers belonging to providers of these technologies or data storage companies. Companies around the world, including supply chain actors, accumulate significant amounts of data every day. However, they do not always have the proper resources, infrastructure and qualified personnel to effectively use this data.

One of the main obstacles for companies that use cloud computing is the lack of properly trained personnel. However, cloud service providers can help solve this financial, cultural, and practical challenge. In other words, they offer expertise in building and securing cloud environments that an in-house team with extensive credentials and experience doesn't have.

Another problem of the implementation of cloud computing is the inconsistency of the functionality of cloud services with the needs of logistics companies. In this regard, there is a need for a comprehensive study of the functionality of cloud computing services and the possibilities of their use in logistics companies for cloud-based supply chain management and digital accounting. So, the aim of this study is to determine the capabilities of

cloud services to meet the needs of logistics companies in the management of supply chains and digital accounting based on cloud computing.

Cloud services are gaining more and more popularity for their use in accounting. This is because they ensure the reliability of accounting data storage and the possibility of accessing them anywhere in the world. In addition, cloud services offer the possibility of automating certain accounting processes. This reduces the workload on accounting department employees and increases their productivity.

The aim involved the fulfilment of the following research objectives:

- Study the existing models of cloud service maintenance.
- Analyse the functionality of the most popular cloud services for their use for computing in the field of supply chain management and digital accounting in logistics companies.

2 Literature review

Author states that global supply chains are undergoing significant transformations caused by the use of cloud technologies, [1]. The concept of cloud computing and machine learning can be effectively used in the field of supply chain management, facilitating collaboration between supply chain stakeholders through the integration of supply chain activities and predictive analytics. Cloud computing enable building optimized delivery routes, analysing the stage of delivery in real time, and make adjustments to the planned route to take into account changes in circumstances.

The use of cloud technologies enables the transition to Industry 4.0, which is a powerful impetus in the development of customer satisfaction for logistics companies. Authors noted that Logistics 4.0 is a relatively new field of research that requires the development of scalable and effective software solutions and their deployment for successful business process transformations, [2]. In this aspect, the transformation of the information subsystem of logistics companies, in particular digital accounting, is worth noting. The use of cloud computing and the implementation of Industry 4.0 elements enables receiving operational information online, which significantly increases the effectiveness of information support for decision-making.

Researchers indicate that the integration of supply chain participants through cloud systems provides each participant with access to important information and facilitates the synchronization of supply chains [3]. Logistics capacity management becomes more efficient due to the full use of available assets and resources. Global freight planning enables companies to exercise better control and ensure timely decision-making, which provides greater flexibility in the supply chain. The cloud technologies and software are applied to integrate all aspects of the supply chain thanks to the accounting system, which becomes automated to a certain extent. In this sense, the accountant's role is being transformed, shifting from the performance of traditional accounting functions of recording the economic facts to the management of available information.

In the dissertation, author notes that the use of cloud computing can have a number of positive effects for logistics companies, but the effectiveness depends to a large extent on how the use of these technologies has been organized [4]. The author notes that the correctly chosen model of the introduction of cloud computing tis adapted to a specific logistics company and the specifics of the organization of information flows is decisive in the effectiveness of the transition to the use of cloud technologies. It is also necessary to take into account the organization of digital accounting in the logistics company, and cloud technologies should maximally provide the needs of the accounting system in particular.

Dfreight [5] detailed the issue of the advantages of using cloud computing by logistics companies. The general advantages, such as reducing costs, increasing efficiency, and improving the decision-making process, also include those directly related to the accounting system — receiving data in real time, automating the process of placing orders, implementing a data-based management system. So, the accounting system at the logistics enterprise also undergoes transformations, which contributes to its improvement.

After the coronavirus pandemic, many logistics companies have transformed their business models in response to new risks. This is why cloud software products should also be adaptive and meet the adaptation needs when necessary, [6,7]. Many software products do not take into account current trends in changing business models of logistics companies, which makes it necessary to identify modern needs in mathematical calculations of users of cloud computing platforms.

Cloud computing significantly increases the efficiency of decision-making, [8,9]. Previously, logistics companies had to invest a lot of resources to ensure the transparency of the logistics process, while cloud technologies make it completely transparent. Customers can monitor freight movement in real time. Cloud technologies also decentralize the decision-making process. Each section of the logistics chain becomes independent in making current decisions, which significantly increases the flexibility and speed of the decision-making system. Flexibility is provided by a well-established accounting system, which also becomes decentralized. Most of the data are registered on the spot, the storage and processing of information becomes automated, and the reporting is provided on demand at any management level.

An important aspect of the implementation of cloud computing is the transformation of information flows within the logistics company and between the logistics company and its customers, [10,11]. Cloud computing gives external employees the ability to access information

and download data and documents from or to a particular storage space via a web link on any device. The information network of a logistics company can be significantly expanded, and the information system can contain information entry points at almost every stage of the logistics chain. This structure of the information system makes it extremely flexible, which ensures the completeness of information even in the most complex logistics channels.

Cloud technologies provide digitalization of business, [9,12]. Digitization allows not only to optimize individual business processes through the use of digital mathematical calculations based, but also to change the very concept of the company's interaction with its customers. The use of cloud computing optimizes the logistics company's business processes in terms of interaction with customers and obtaining the necessary information from them. The customers upload all necessary links to the system. Moreover, they can monitor freight movement. Access to the necessary documentation is provided in a similar way — each customer can independently download the contract and other documents from the information system. Any changes in the terms of delivery are automatically recorded and updated in the relevant documentation.

3 Methods

The research will be conducted in two stages. The first stage involves the study of the existing cloud services maintenance models, as the logistics company's decision to use such a service and the ability to meet the needs of the logistics company in performing mathematical calculations may depend on this.

The second stage provides for the analysis of the functionality of the most popular cloud service providers for their use for mathematical calculations in the field of supply chain management in logistics companies. The opportunities that the cloud services offer for improving the digital accounting system in logistics companies will also be analysed separately. The research sample included 5 of the most popular cloud services used by companies, [13]:

1. Amazon Web Services [14].
2. Microsoft Azure [15].
3. Google Cloud Platform [16].
4. Oracle Cloud [17].
5. SAP Cloud Platform [18].

The criteria for the ability of cloud services to meet the needs for improving the digital accounting of logistics companies include the following:

- Data storage on cloud service.
- Data scaling of the accounting system in case of increasing data volumes.
- Mathematical calculations for automation of accounting processes related to data processing.
- Registering economic transactions and economic facts automatically using the Internet of Things.
- Visualization of accounting data.
- Specialized financial blocks for work on planning, control, budgeting, etc.
- Data exchange with other services.
- Managing cash flows and financial calculations.
- Real-time monitoring and cost management capabilities.

The capabilities of each cloud service to meet the requirements for improving the accounting system in logistics companies through computing will be determined based on the analysis and comparison of the capabilities of cloud services of different provider companies.

The analysis of literature and official documentation on the possibilities of cloud computing services to meet the needs of improving the accounting of logistics companies involved the following scientific methods:

Review of current academic publications: this method allows for a selection, review and analysis of academic publications related to the possibilities of cloud computing for accounting. It includes a thorough literature search, selection of relevant studies, and analysis of the results to determine the current state of research in this field.

Analysis of official documentation. This method includes reviewing the official documents of the provider companies about the functionality of their products. This analysis will help to identify the requirements to be met to use cloud computing in accounting, and the opportunities it provides.

Expert evaluation. This method involves the use of the authors' opinion about the possibilities of using cloud computing to meet the accounting needs of logistics companies.

A parametric modeling method for building a model of the influence of the functionality of cloud services on the level of meeting the needs of the accounting system of logistics companies. The conceptual basis of the parametric model consists of determining the level of satisfaction of the needs of the accounting system of logistics companies as a function of the parameters and capabilities of cloud services. The available functionality of the considered cloud services represents Independent variable models.

4 Result

In this study, cloud services are supposed to mean a technology that provides access to a set of configurable mathematical computing resources, such as networks, servers, data stores, applications and/or services. Our understanding is based on a combination of conceptual principles of building cloud services, [19], types of mathematical calculations provided by cloud services, [20], and predictive assessments of the development of cloud computing technologies and services, [21]. The users can quickly use these resources for their tasks, reducing the number of interactions with the service provider or their

own management resources. Cloud services include three service models (Figure 1).

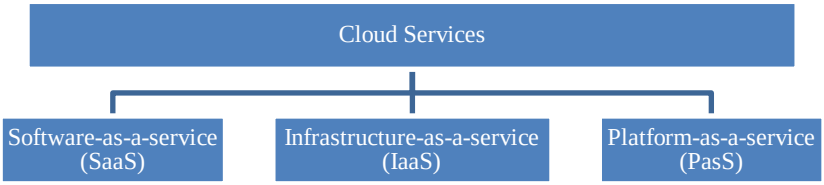

Figure 1 Cloud services maintenance models

The SaaS model involves a company using programmes or web applications that are developed, hosted, and maintained by a third party. For example, it can be programmes for planning and managing company flow of resources.

The IaaS model involves a business model where a company uses cloud computing for data management and analysis of logistic flows. This infrastructure can include various components such as Internet of Things (IoT) sensors, virtual machines, networking technologies, and energy management infrastructure.

The PaaS model is designed for application developers who need a stable cloud environment to test cloud services and verify their compatibility with existing products and application programming interfaces (APIs).

The use of cloud computing plays an important role in the transformation of digital accounting of logistics companies when transitioning to the use of such services. Cloud services enable storing accounting data in a centralized cloud storage, which provides access to them from any place and device. This makes it easier to share and collaborate with data and flow of information between different departments and employees. Cloud services typically have high security standards, including data encryption, backups, and tamper protection. This is important for accounting of sensitive financial data.

The use of cloud services partially automates accounting processes. Cloud services often have built-in automation features, such as electronic invoicing, automatic tax accounting, and payroll. This helps reduce manual work and errors, while increasing the efficiency of accounting processes. Besides, cloud services enable integrating the existing accounting platform with other systems.

Cloud services can be integrated with other systems, such as supply chain management systems (SCM), warehouse management systems (WMS) and others. This allows for automatic data exchange and provides a single information platform for accounting and other functional areas.

The most popular cloud services used by logistics companies are considered and the solutions they offer for improving digital accounting are analysed below (Figure 2).

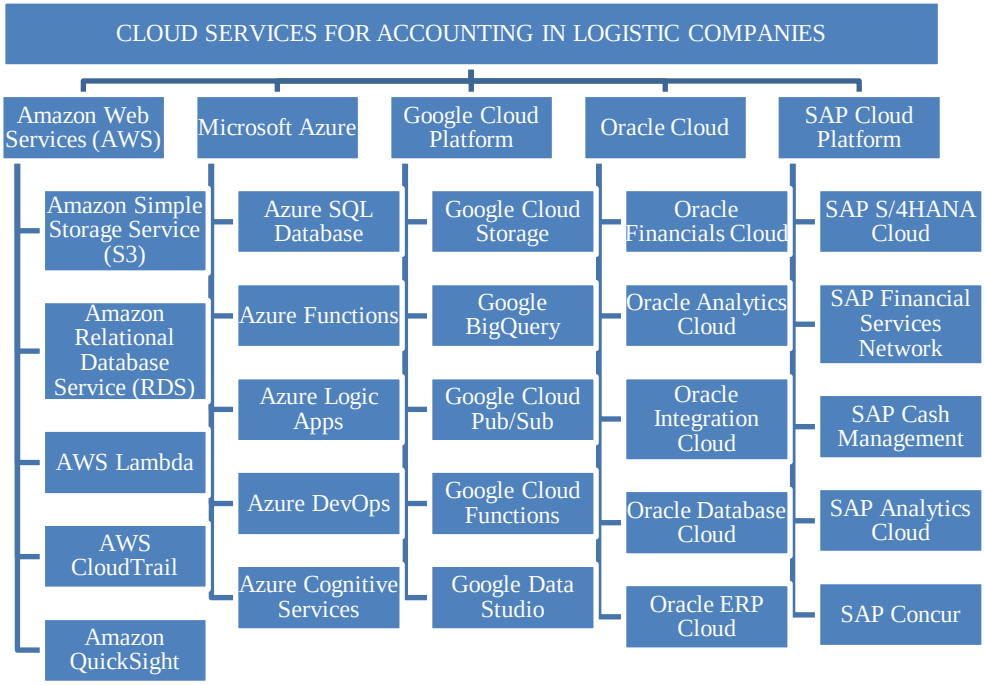

Figure 2 Cloud services that can be used to improve the accounting system in logistics companies

1. Amazon Web Services (AWS).

Amazon EC2 (Elastic Compute Cloud) is a highly scalable cloud computing service. It provides resizable virtual servers that enable companies to quickly scale their computing resources according to their needs. For logistics and supply chain management, EC2 enables companies to deploy their applications and systems, such as inventory management software or transportation optimization tools, on a reliable and scalable infrastructure.

Amazon S3 (Simple Storage Service) provides companies with a reliable platform for storing and retrieving any amount of data at any time. In the context of logistics and supply chain management, S3 can be used to store large data volumes, such as product information, shipment records, or sensor data from IoT devices, enabling easy access, analysis, and integration with other systems.

Amazon Redshift is a fully managed petabyte-scale storage service. It enables companies to efficiently analyse large data volumes to gain valuable insights and make data-based decisions. In logistics and supply chain management, Redshift can be used to store and analyse huge amounts of historical data related to inventory levels, sales trends, customer behaviour or supplier performance. It enables businesses to run complex queries, generate reports and run analytics to optimize various aspects of the supply chain, such as demand forecasting, inventory management or supply chain risk assessment.

Amazon Web Services offers a variety of services and solutions that can contribute to the improvement of accounting in a logistics company that is transiting to the use of cloud services. The company's products that can be directly used to improve the accounting system will be detailed below.

Amazon Simple Storage Service (S3) in a logistics company can be used to store accounting data, such as financial statements, payments, invoices, as well as other documentation related to financial transactions. S3 ensures data reliability and availability, as well as the ability to easily backup and restore data when needed.

Amazon Relational Database Service (RDS) enables creating and managing relational databases in the AWS cloud environment. This can be useful for storing and managing accounting data in a structured format. RDS supports different types of databases, such as MySQL, PostgreSQL, or Oracle, and provides scalable resources to ensure performance and data availability.

AWS Lambda is a serverless computing service that executes code without the need to manage infrastructure. This can be useful for automating accounting processes and performing routine tasks. For example, a Lambda function can be created to automatically account for payments or generate financial reports based on input data.

AWS CloudTrail is a monitoring and event accounting service used to monitor, verify, and analyse activities in the AWS cloud environment. This can be useful for ensuring compliance and security of accounting transactions. CloudTrail logs all events related to operations in AWS services, thereby enabling to establish monitoring of changes, identify potential problems or unauthorized access.

Amazon QuickSight is a data visualization service to create interactive reports and charts based on accounting data. It makes the analysis of financial data more understandable and accessible to various stakeholders. QuickSight provides a variety of visualization tools and the ability to share reports with colleagues and partners.

2. Microsoft Azure.

Azure IoT Hub is a cloud service that provides secure connection and management of devices. It provides a centralized platform for managing IoT devices in logistics and supply chains. The companies use IoT Hub to securely connect, monitor, and remotely manage a wide range of devices such as sensors, trackers or gateways involved in the supply chain ecosystem. It enables the acquisition, processing and analysis of data in real-time, allowing companies to track and monitor assets, monitor the state of the environment or detect anomalies. IoT Hub also integrates with other Azure services, such as Azure Functions or Azure Machine Learning providing real-time decision making, predictive analytics, and automation of supply chain processes.

Azure Functions is a serverless computing service used by companies to run event-based applications and workflows. This enables businesses to execute code or functions driven by particular events or triggers without worrying about the underlying infrastructure. Logistics companies can use Azure functions to automate a variety of processes and tasks, such as order processing, inventory replenishment, or shipment tracking. For example, businesses can create functions that trigger inventory alerts when inventory levels reach a threshold, or functions that process incoming orders and initiate execution processes. Azure functions provide flexibility, scalability and cost-effectiveness by running code only when needed, enabling companies to build efficient and responsive supply chain management systems.

Azure Machine Learning is a cloud service used by companies to build, deploy, and manage machine learning models. It provides a complete set of tools and services for all stages of the machine learning lifecycle, including data preparation, model development, training, evaluation, and deployment. In logistics and supply chain, Azure machine learning can be used to perform mathematical calculations to develop predictive models to forecast demand, optimize inventory levels, or optimize route and transportation planning. The analysis of historical data enables businesses to build machine learning models that accurately predict demand patterns, optimize inventory allocation to reduce shortages or overstocks, or optimize delivery routes to minimize costs and improve customer satisfaction. Azure

Machine Learning integrates with other Azure services, such as Azure IoT Hub or Azure Databricks, to use IoT data or big data analytics for learning and insights, enabling companies to make data-based decisions and improve supply chain efficiency.

Microsoft Azure offers a variety of services and solutions that can contribute to the improvement of accounting in a logistics company. For example, Azure SQL Database is a fully managed database that offers high levels of security, availability, and scalability. It can be used to store and manage accounting data in a cloud environment.

Azure Functions is a serverless service used to execute code driven by events or triggers. It can be applied to automate accounting processes and perform routine tasks. For example, you can create an Azure Functions feature that automatically processes and records accounting transactions, such as payments or logging business transactions.

Azure Logic Apps is a service for creating automated workflows driven by events and actions. This can be used to integrate accounting data and perform various actions such as sending payment notifications or generating financial reports.

Azure DevOps is a set of tools and services for software development and development lifecycle management. It can be used to develop and maintain internal accounting systems or integrate external accounting data processing solutions.

Azure Cognitive Services offers a set of intelligent services that can be used to analyse and process text data, including financial reports and payments. For example, the Form Recognizer service can automatically extract and analyse structured information from accounting documents, such as the text part of a report.

3. Google Cloud Platform (GCP).

Google Cloud Platform is a scalable and highly available object storage service used by companies to store and access their data from anywhere in the world. It provides security and performance for storing different types of data, including unstructured and structured data. Logistics companies can use Google Cloud Storage to store large data volumes, such as product catalogues, shipment records, or sensor data from IoT devices. Data can be easily accessed, shared, and integrated with other Google Cloud services or third-party applications. Google Cloud Storage provides different classes of storage according to different access models and cost, enabling businesses to cost-effectively store their data while maintaining high availability, perform appropriate mathematical calculations.

Google BigQuery is a fully managed serverless data storage for companies to rapidly analyse large data volumes. It offers a highly scalable and distributed architecture for executing SQL queries for large datasets. BigQuery can be used in logistics and supply chains to perform advanced analytics, generate reports, and gain insights from large volumes of historical data related to sales, inventory, customer behaviour, or supplier performance. By analysing these data, businesses can identify trends, make data-based decisions, and optimize various aspects of the supply chain, such as demand forecasting, inventory management, or supplier selection. BigQuery perfectly integrates with other Google Cloud services and tools, enabling companies to ingest and analyse data from multiple sources and gain valuable insights to improve supply chain operations.

Google Cloud Pub/Sub is a messaging service used by companies to build event-driven real-time systems. It provides reliable and scalable messaging capabilities to decouple and integrate different components of the supply chain ecosystem. Cloud Pub/Sub can be used in logistics and supply chain management to stream real-time data, such as order updates, inventory alerts, or sensor data, to different systems and applications. For example, companies can use Pub/Sub to send notifications to inventory management systems about changes in inventory levels or to trigger notifications to transportation management systems about delayed deliveries. Cloud Pub/Sub provides durability, reliability and low latency for message delivery, ensuring a continuous flow of critical information throughout the supply chain, enabling real-time monitoring, decision-making, and automation.

Google cloud services offer similar opportunities for improving accounting in logistics companies as other services. Google Cloud Storage is a reliable object storage used to store accounting data and documents in a secure environment. With flexible storage options, companies can store, organize and back up data for accounting, and provide easy access to it for analysis and processing.

Google BigQuery is a data storage and analytics service for efficient analysis of large data volumes based on mathematical calculations. With powerful processing tools and fast queries, BigQuery can be used to analyse financial data, reports, transactions and other accounting data. This enables companies to obtain valuable insights and perform detailed analysis to make financial and management decisions.

Google Cloud Pub/Sub is a messaging service that enables streaming data exchange between different systems and components. This can be used to communicate updates in the accounting system, notifications or updates between different accounting and reporting systems. Pub/Sub provides reliable and scalable communication that facilitates efficient real-time data exchange. This is especially relevant in a dynamic external environment, where the speed of decision-making is an important component of business success.

Google Cloud Functions is a serverless cloud computing service that used to execute code and functions according to programmed events. It can be used to automate accounting processes and perform accounting routine tasks. For example, Cloud Functions feature can be

created that automatically processes and analyses event-based accounting data or generate reports.

Google Data Studio is a free data visualization tool for creating interactive reports and charts based on accounting data. It helps to analyse financial data making them more understandable to various stakeholders. Data Studio enables creating customized reports, charts, infographics, and dashboards for tracking and displaying key performance indicators.

4. Oracle Cloud.

Oracle Supply Chain Management (SCM) Cloud is a comprehensive set of programmes designed to optimize supply chain operations. It covers a wide range of functions, including inventory management, order execution, procurement, logistics and transportation management. Oracle SCM Cloud enables companies to obtain comprehensive analytics and control over their supply chain processes. It provides tools for demand planning, supply planning, and inventory optimization, helping businesses to optimize inventory levels, minimize inventory shortages, and reduce transportation costs. The businesses use the capabilities offered by this cloud service based on mathematical calculations in terms of order execution allows to effectively manage orders, track shipments, and ensure timely delivery. Oracle SCM Cloud also offers features for supplier management, enabling companies to collaborate with suppliers, manage contracts, and track supplier performance. Businesses use Oracle SCM Cloud to improve supply chain efficiency, improve customer satisfaction, and reduce costs by optimizing various aspects of their supply chain operations.

Oracle Cloud also offers a variety of services and solutions that can improve accounting in a logistics company. Oracle Financials Cloud is a fully integrated financial management system that provides extensive accounting, financial planning, and analysis capabilities. This system is designed to store, track and analyse financial transactions, including payment accounting, reporting, budget control, and asset management.

Oracle Analytics Cloud is a service for analytics and visualization of mathematical calculations used to analyse accounting data, create informative reports and charts. This service helps logistics companies to obtain important data on financial status, profitability, costs, and other financial indicators.

Oracle Integration Cloud is a digital solution for data and application integration. This service enables communication between different accounting systems used in the logistics company and data exchange between them. This contributes to the automation of accounting and ensuring the relevance of data in various systems.

Oracle Database Cloud provides a digital environment for storing and managing accounting data. This allows the logistics company to ensure security, availability and efficient management of financial data.

Oracle ERP Cloud is a comprehensive enterprise management solution that includes modules for accounting, finance, inventory management, procurement management and many others. This service allows the logistics company to keep accounting records, track financial information and make adjustments according to requirements.

5. SAP Cloud Platform.

SAP Integrated Business Planning (IBP) is a cloud service designed for businesses to match supply and demand, optimize inventory levels, and improve overall supply chain performance based on mathematical calculations. It provides a common environment for sales and operations planning, demand planning, inventory optimization and management. With SAP IBP, companies can use advanced analytics, machine learning, and modelling capabilities to accurately forecast demand, optimize inventory levels, and balance supply and demand. It provides real-time visibility of the supply chain, enabling companies to identify potential bottlenecks, mitigate risks, and make proactive decisions. SAP IBP integrates with other SAP solutions such as SAP S/4HANA, enabling comprehensive supply chain integration and data synchronization. SAP IBP helps companies to achieve better supply chain visibility, increase operational efficiency, reduce costs, and improve customer service.

SAP Extended Warehouse Management (EWM) is another comprehensive warehouse management solution that provides advanced features for efficient and optimized warehouse operations. SAP EWM offers functions for inbound and outbound processes, inventory management, storage optimization, workforce management, and transportation integration. Businesses use SAP EWM to effectively manage the processes of goods receipt, receiving, order picking, packing, and shipping, ensuring accurate and timely order execution. The solution provides real-time visibility of warehouse operations, enabling businesses to optimize the use of warehouse space, improve inventory accuracy and labour productivity. SAP EWM integrates with other SAP solutions, such as SAP S/4HANA or SAP Transportation Management, providing comprehensive visibility and synchronization of the supply chain. The companies use SAP EWM to increase warehouse throughput, reduce errors, improve inventory accuracy and customer satisfaction.

SAP Cloud Platform offers various services and solutions for the accounting system of logistics companies. SAP S/4HANA Cloud is a cloud version of an integrated enterprise management system that includes finance, accounting, inventory control and other modules. This allows the logistics company to effectively keep accounting records, manage financial processes and ensure the accuracy and integrity of financial information.

SAP Financial Services Network (FSN) is a network of electronic data exchange and collaboration between companies in the financial services industry. It helps

logistics companies to connect with banks, financial service providers and other counterparties to automate accounting operations such as paying bills, accounting for payments and feedback to financial institutions for settlement reconciliation, among other things.

SAP Cash Management is a cash flow management and forecasting solution. This service enables the logistics company to effectively monitor, manage and forecast cash flows, including incoming and outgoing payments, ensuring accuracy and flexibility in managing cash resources.

SAP Analytics Cloud is a data analytics and visualization service based on relevant mathematical calculations designed to analyse financial data and create reports, charts and infographics. The logistics companies use this service to receive data on financial status, profitability, costs, and other financial indicators.

SAP Concur is a cloud-based solution for cost and transportation management. It helps logistics companies to effectively track, manage, and report on expenses related to accounting operations, transportation, and business trips. This improves cost efficiency and ensure cost accounting accuracy across activities.

Table 1 Capabilities of cloud services for improving the accounting system in logistics companies based on mathematical calculations

Service capabilities	Cloud service				
	Amazon Web Services (AWS)	Microsoft Azure	Google Cloud	Oracle Cloud	SAP Cloud Platform
Data storage - storage of accounting data and documents	Amazon Simple Storage Service (S3)	Google Cloud Storage	Google Cloud Storage	-	-
Database - storage, management and scaling of accounting data	Amazon Relational Database Service (RDS)	Azure SQL Database	-	Oracle Database Cloud	-
Serverless mathematical calculation - automation of accounting processes and performance of routine tasks	AWS Lambda	Azure Functions	Google Cloud Functions	-	-
Monitoring and accounting of the economic facts - tracking, analysis and security of accounting operations	AWS CloudTrail	-	-	-	-
Data visualization – creation of interactive reports and charts based on accounting data and mathematical calculations	Amazon QuickSight	-	Google Data Studio	-	SAP Analytics Cloud
Financial management – accounting, financial planning, budget control and asset management	-	-	-	Oracle Financials Cloud	SAP S/4HANA Cloud
Electronic data exchange – automation of accounting operations and accounting of payments	-	-	-	-	SAP Financial Services Network (FSN)
Cash flow management – tracking, managing and forecasting cash flows	-	-	-	-	SAP Cash Management
Cost and transportation management - tracking, management and reporting of costs related to accounting operations, transportation, and business trips	-	-	-	-	SAP Concur

The analysis of the capabilities of the leading cloud platforms gives grounds to conclude that there are several common capabilities that can contribute to the improvement of accounting in logistics companies. All these platforms provide various services for data storage, such as object storage and databases, as well as serverless computing, to automate accounting processes and perform routine tasks. They also offer data visualization services to help understand financial data and create reports on flow of financial information.

However, each of these platforms has its peculiarities. For example, Amazon Web Services focuses on reliability and scalability, providing a wide range of data storage and processing services. Microsoft Azure stands out for its integrated solutions and services for data management and analytics. Google Cloud offers a wide range of tools for development and analytics, including data visualization and data sharing. Oracle Cloud provides comprehensive financial and database management solutions. Finally, SAP Cloud Platform specializes in financial management and analytics solutions.

To decide on choosing a cloud service to improve the organization of accounting in the company, we suggest using a parametric model of compliance of the

functionality of cloud services with the needs of the accounting system (1):

$$EOA = f([DSEi + DBEi + SEi + MEi + DVEi + FMEi + EDEi + CFMEi\_EMEi]/n) \quad (1)$$

where:
EOA – Efficiency of accounting;
DSE – Data Storage Efficiency;
DBE – Database Efficiency;
SE – Serverless Efficiency;
ME – Monitoring Efficiency;
DVE – Data Visualization Efficiency;
FME – Financial Management Efficiency;
EDE – Electronic Data Efficiency;
CFME – Cash Flow Management Efficiency;
EME – Expense Management Efficiency;
i – cloud service;
n – the number of parameters of cloud services.

Each parameter is assigned a coefficient from 0 to 1, where 0 does not fully meet the needs of the company's accounting system, and 1 fully meets the needs of the company's accounting system. This coefficient is determined by specialists in the company's accounting department, who conduct such an evaluation of cloud services. Based on the calculation results, a parameter is determined that reflects the level of compliance of cloud services' functionality with the accounting system's needs.

In general, the choice of a cloud accounting platform depends on the specific needs of the company. It is important to consider functional requirements, security level, availability, and integration capabilities. Each of these platforms has its own advantages and unique capabilities that help logistics companies improve accounting and make better financial and management decisions.

5 Discussion

The results of this research indicate broad prospects for the use cloud computing by the logistics companies, not only in supply chain management, but also in accounting organization. Analysis of the implementation of cloud computing of the most common cloud platforms revealed significant prospects for improving the accounting of logistics companies. Our conclusions are supported by the results of a study on the impact of cloud computing on accounting in companies, [22]. The authors note that cloud technologies became widespread in accounting during the coronavirus pandemic. Companies tried to comply with quarantine restrictions and introduced cloud services. For accounting, this has opened up significant opportunities in terms of automation of routine processes.

The study [23] on the process of transition to cloud services is interesting. The authors established that the most significant factor in the success of using cloud services in accounting is their compatibility with the company's systems and technologies. This conclusion is confirmed by the results of our research, because the use of different cloud service platforms can be difficult. Each company that provides access to its cloud services tries to provide a complete ecosystem that does not involve the use of third-party components.

Another study [24] proved that cloud computing provides cost reduction and increased productivity of accounting departments. Furthermore, it improves such business processes as communication, working with documents, and the corporate information system. We agree with this conclusion, as the analysis of cloud services identified specialized products and modules for optimizing such business processes. Similar conclusions are drawn in the study [25,26], where the authors note that cloud technologies and artificial intelligence provide such significant advantages that accounting will be completely transferred to cloud services.

Ou and Zhang [27] point out that cloud services are more suitable for small and medium-sized businesses. Small and medium-sized businesses are more flexible and adaptable, which facilitates their transition to cloud services. However, the results of our research indicate that the cloud infrastructure is more focused on large companies, providing great opportunities for the analysis of accounting data and the automation of accounting processes.

Other studies [28,29] analyse the benefits and risks of using cloud computing. One of the most common risks is data insecurity. However, our research showed that large cloud service providers ensure reliable data storage and encryption to minimize insecurity risks. This gives grounds to conclude that cloud services designed for small companies may have certain problems with data insecurity, but large companies that offer a complete cloud computing infrastructure significantly minimize such risks. The advantages over the disadvantages of cloud computing for its use in accounting are also reported in [30,31]. The main advantages include routine tasks automation and reduction of resources for performing analytical functions of accountants. The novelty of the obtained results is the generalization and structuring of information about the possibilities of cloud computing to satisfy the need for supply chain management and for the organization of accounting of logistics companies.

6 Conclusions

The increasing amounts of data on the activities of logistics companies necessitates the search for technical solutions for managing these data. Cloud computing services offer various data management options not only for managing supply chains of logistics companies, but also for accounting system data.

AWS and Google Cloud offer a wide range of data storage and processing services, such as object storage and databases. Azure and Oracle Cloud also provide these

capabilities, but focus on integrated data management solutions. SAP Cloud Platform has limited capabilities in this area. AWS, Azure, and Google Cloud offer serverless math computing services that allow you to automate accounting processes and perform routine tasks. SAP Cloud Platform provides limited capabilities in this area, while Oracle Cloud does not have direct serverless computing services. AWS, Azure, Google Cloud, and SAP Cloud Platform offer services for analysing and visualizing accounting data for better understanding of financial information and creating reports. Oracle Cloud has limited capabilities in this area. Oracle Cloud and SAP Cloud Platform focus on finance, accounting and financial process management solutions, providing comprehensive integrated solutions. Other platforms also have some capabilities in this area, but not as broad and integrated. Consider cloud services that can satisfy the vast majority of logistics companies' accounting system needs. If there are specific needs, the provider companies offer opportunities to develop additional modules to solve such tasks. In addition, these services are constantly being improved, and are flexible in their orientation to meet customers' needs.

In general, each of the cloud platforms has its own advantages and unique capabilities in supporting management of information flows. AWS and Google Cloud provide a wide range of data storage and processing services, Azure and Oracle Cloud offer integrated solutions for data management and analytics, and Oracle Cloud and SAP Cloud Platform specialize in solutions for managing finances and financial processes. The choice of a cloud platform depends on the company's specific needs and its accounting priorities.

The proposed parametric model can be used by logistics companies' accounting department employees when choosing cloud services. Based on a subjective assessment of the accounting system needs of their company, they can use this model to identify the cloud service that best meets their needs. The obtained results can be applied in the development of a model for the transformation of databases of logistics companies and the selection of a cloud computing service for the information system migration.

The conducted research opens up prospects for further research, in particular, regarding the problems of integrating services built on different platforms and finding optimal solutions for combining the information system existing in a logistics company with the offered cloud computing services.

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The constructivist approach as a concept of active learning and teaching of optimization processes at technical universities

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Abstract: As we move toward a more competitive global economy, the demand for highly qualified people to create and manage more efficient logistics systems, such as flows and management of materials or information, human flows, and supply chains, increases. Without logistics, the commercial world would grind to a halt. Businesses depend on logistics professionals to keep production and delivery moving forward which makes logistics education crucial. Companies expect their future employees to gain practical information, and to master what they are learning. Students must know how to apply what they learn. This is a reason why increasing importance is attributed to the constructivist approach to teaching and learning in university education. Through experiments or simulation of processes, and group work based on previous experience and knowledge, students better uncover the laws of phenomena. By actively engaging in the learning process, deeper and long-term applicable knowledge about the studied processes is acquired. The goal of this article is to implement the constructivist approach in the education of operational research and logistics at technical universities.

1 Introduction

The constructivist approach to learning and teaching has recently become very popular in school education. The idea that knowledge is a human construction supported by experience, first stated by Vico in the 18th century and further extended by Kant, greatly affected the epistemology of Piaget, who is considered to be the forerunner of the constructivism theory for the process of learning. This theory was formally introduced by von Glasersfeld who developed his ideas in the Piaget Foundation of the United States in 1975 [1].

According to the constructivist view, knowledge is not passively received from the environment but actively constructed by synthesizing past knowledge and experience with new information. The "coming to know" is a process of adaptation based on and constantly modified by the individual's experience of the world [1-3].

In recent years, constructivism approach has gained popularity in teaching and learning of mathematics in primary and secondary education. However, in tertiary education, it seems that most teachers still prefer the traditional way of delivering explicit mathematics instruction. While processes studied in primary and secondary schools are relatively simple, problems tackled at the university level are more complex, time-consuming, and often span across various branches of knowledge. Therefore, incorporating constructivist approach to solving such tasks is significantly more challenging. Nevertheless, universities need to integrate such working methods into the educational process so that students are compelled to contemplate the causal relationships of processes and actively seek problem-solving strategies [4,5]. Actively solved tasks urge students not to rely on algorithmic solutions but encourage them to think about the factors influencing the course of processes, develop the ability to choose suitable problem-solving methods, work in groups, listen to others, and effectively present and defend their opinions [6,7]. Students educated in this manner subsequently achieve better results in their studies and practice [5,8]. Moreover, an increasing number of students in primary and secondary schools are being educated using constructivist methods, therefore universities should be prepared for these students.

Mathematics has been recognised as a subject that enhances higher order skills because on the one hand, it requires abstract thinking, and on the other, promotes use and application of knowledge [9,10]. At first, it is essetial to identify an area of mathematics suitable for a constructivist teaching approach. One excellent area is operational research and logistics, specifically optimization problem-solving. Nowadays, each modern technical expert is required to have some awareness and sensitivity to the logistical flow of materials and information during the production process [11,12]. In the field of process optimization, a significant number of modified problem-solving methods have been developed. These methods are mostly iterative, generating a sequence of solutions in which each subsequent solution achieves a better value in terms of optimizing the process. Graphical and simplex methods are fundamental methods among the approaches to solving optimization problems in standard form with two decision variables [13]. Naturally, it is possible to use appropriate mathematical software to solve optimization problems, but we recommend to introduce this tool only after students have mastered and understood the principles of solving such problems. Software tools are suitable for solving other types of optimization problems that involve a larger number of variables, constraints, or problems not in standard form, and allow us to find solutions to solved problems quickly. However, without an

understanding of the essence of problem-solving, progress in exploring new methods and approaches to solving optimization problems can not be made.

A new interesting approach to solving optimization problems is combining both fundamental methods simultaneously. That enables students to observe the sequence of problem-solving steps, not only from an algorithmic perspective but also to perceive the graphical significance of these steps, which, in turn, helps them understand the logical coherence of the algorithm steps. Therefore, students are encouraged to consider and find connections that are often overlooked in algorithmic problem-solving. In the presented preparatory phase, the step-by-step solution of the chosen problem is linked with challenging questions and discussion with students to support critical analysis of the mathematical content. Working in groups is recommended, and students' ideas are continuously presented.

2 Linear programming problem

Let's consider a linear programming problem (LPP) in the standard form. That means,
Let's maximize the objective function (1)

$$z(x_1, x_2, \dots, x_n) = \sum_{j=1}^{n} c_j x_j, \qquad (1)$$

subject to (2)

$$\sum_{j=1}^{n} a_{ij} x_j \le b_i, \qquad (2)$$

$$x_j \ge 0,$$

for $b_i > 0,\ i = 1, 2, \dots, m,\ j = 1, 2, \dots, n.$

Let's choose a specific linear programming problem and demonstrate the proposed working method with students. The solved LPP is as follows:

The firm produced two kinds of products P_1 *and* P_2. *The production is limited by the quantity of resources* S_1 *and* S_2 *and machines' capacity M per month. There are 1800 units of resource* S_1 *and 1600 units of resource* S_2 *per month. Machines M are capable of being operated for at most 860 hours per month. Each piece of product* P_1 *requires 6 units of resource* S_1 *and 1 unit of resource* S_2. *Each piece of the product* P_2 *requires 3 units of resource* S_1 *and 4 units of resource* S_2. *Both products* P_1 *and* P_2 *require 2 hours of processing time on machines M. On each sale, the firm makes a profit of 3€ per piece of product* P_1 *sold and 4€ per piece of product* P_2 *sold. How many of each type of products should be produced to maximize the total monthly profit?*

2.1 Mathematical formulation of LPP

At first, the solved linear programming problem is mathematically formulated. This step might be demanding for students. They need to realize the desired relationships between variables and recognize technological parameters with their impact on maximizing the objective. Therefore, creating more mathematical models of optimization problems with students is highly recommended.

How can the provided information be structured clearly? Creating a table of given data helps to organize and structure the provided information and leads to a better understanding of the mathematical model construction process. The input data of the solved problem can be written in the form of the following table, Table 1.

Table 1 Input data of the solved LPP

	Product P_1	Product P_2	Available quantity
Resource S_1	6	3	1800
Resource S_2	1	4	1600
Machines M	2	2	860
Profit	3	4	

According to a standard form of LPP and Table 1, the mathematical formulation of the solved LPP has the following form:

Let's find the values of two variables, x_1, *and* x_2, *such that they maximize the objective function*

$$z(x_1, x_2) = 3x_1 + 4x_2,$$

subject to the following constraints (3)

$$\begin{aligned} 6x_1 + 3x_2 &\le 1800, \\ x_1 + 4x_2 &\le 1600, \\ 2x_1 + 2x_2 &\le 860, \\ x_1 &\ge 0, \\ x_2 &\ge 0. \end{aligned} \qquad (3)$$

2.2 A constructivist approach to solving LPP

The optimal solution to the solved problem can be found by the graphical method [13]. *How can a mathematical model be graphically represented?* At first, let's plot all inequalities (3) on a graph on the x_1x_2-coordinate plane. *How can the inequalities* $x_1 \ge 0$ *and* $x_2 \ge 0$ *be graphically interpreted?* Since the two decision variables x_1 and x_2 are non-negative, let's consider only the first quadrant of the x_1x_2-coordinate plane. *What do the other constraints graphically mean?* Graphing each constraint, a half-plane is obtained. The first constraint in the first quadrant is represented by a region (Figure 1).

The constructivist approach as a concept of active learning and teaching of optimization processes at technical universities

Marcela Lascsakova

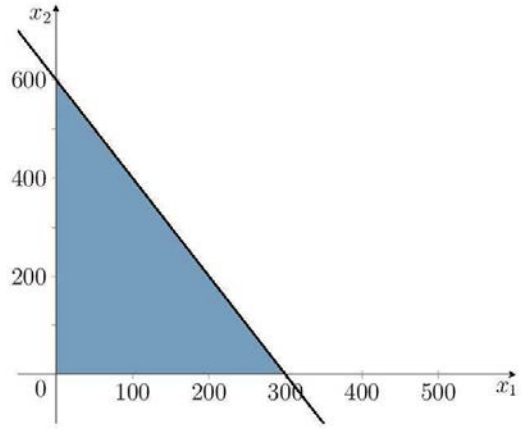

Figure 1 Half-plane $6x_1 + 3x_2 \leq 1800$ *in the first quadrant*

The feasible region is just the intersection of three half-planes in the first quadrant (Figure 2).

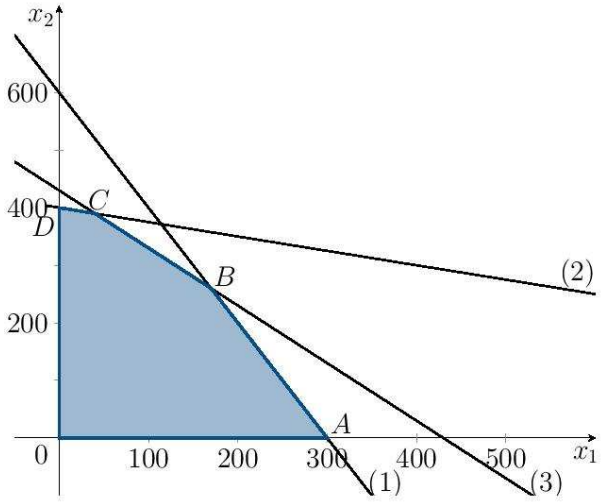

Figure 2 Feasible region

At which point of the feasible region does the objective function $z(x_1, x_2) = 3x_1 + 4x_2$ *reach its maximum value?* By theory, if the feasible region is bounded, then the objective function has both a maximum and a minimum value on the feasible region, and each of these occurs at a corner point (vertex) of the feasible region. *Which vertex of the bounded feasible region maximizes the objective function?* The optimal solution is found by testing the objective function at each vertex. At first, the coordinates of each vertex of the feasible region are found, O=[0;0], A=[300;0], B=[170;260], C=[40;390], D=[0;400]. The coordinates of vertices O, A, and D are visible from the graph. The coordinates of points B, and C are obtained by solving the systems of two linear equations which correspond to equations of intersecting lines. By determining the values of the objective function at each vertex, the maximum value can be found

z(O)=3*0+4*0=0,
z(A)=3*300+4*0=900,
z(B)=3*170+4*260=1550,
z(C)=3*40+4*390=**1680**,
z(D)=3*0+4*400=1600.

The coordinates of vertex C represent the optimal solution of the given maximization problem, $x_1 = 40$, $x_2 = 390$, and z(C)=1680€ is a maximum value, the highest obtained profit of the firm under given circumstances.

Let's analyze determining the optimal solution to the same problem step by step to understand the meaning of performed steps and look for connections in the procedure of solving the task with a graphical solution. Simultaneously, let's look at calculating the solution to the task using the simplex method [13].

How can different limitations of the observed process expressed by a system of inequalities of different types be mathematically unified? A linear programming problem in standard form can be transformed into a system of linear equations. The corresponding system of three constraint equations has the form (4)

$$\begin{aligned} 6x_1 + 3x_2 + s_1 &= 1800, \\ x_1 + 4x_2 + s_2 &= 1600 \\ 2x_1 + 2x_2 + s_3 &= 860, \end{aligned} \tag{4}$$

where $s_1 \geq 0,\ s_2 \geq 0,\ s_3 \geq 0$.

The objective function can be written in the equivalent form

$$-3x_1 - 4x_2 - 0s_1 - 0s_2 - 0s_3 + z = 0.$$

Therefore, the initial tableau of the simplex method is as follows, see Table 2.

Table 2 Initial tableau of the simplex method

Base	x_1	x_2	s_1	s_2	s_3	z	b_i
s_1	6	3	1	0	0	0	1800
s_2	1	4	0	1	0	0	1600
s_3	2	2	0	0	1	0	860
z	-3	-4	0	0	0	1	0

How many solutions have systems of linear equations (4)*?* The system of three constraint equations contains five unknowns. From linear algebra, we know that such a system has infinitely many solutions. *How can solutions be determined?* These solutions can be obtained by arbitrarily choosing the values of two variables and calculating the values of the remaining three variables from the given system of equations (4). Since each slack variable s_i, $i = 1, 2, 3$ appears in exactly one equation, the process of expressing it will be straightforward. After some manipulations, we obtain

$$\begin{aligned} s_1 &= 1800 - 6x_1 - 3x_2, \\ s_2 &= 1600 - x_1 - 4x_2, \\ s_3 &= 860 - 2x_1 - 2x_2. \end{aligned} \tag{5}$$

The values of variables s_1, s_2, and s_3 can be obtained by choosing the values $x_1 = 0$, and $x_2 = 0$. Then, by (5), $s_1 = 1800, s_2 = 1600$, and $s_3 = 860$. This allows us to determine the first basic feasible solution. *What does the initial basic feasible solution mean?* At first, let's consider a production plan where no products P_1 and P_2 are manufactured ($x_1 = 0,\ x_2 = 0$). In that case, the inventory levels of resources S_1 and S_2, as well as the available machines' hours M, remain unchanged, remaining in their original quantities (there are 1800 units of resource S_1 in stock, 1600 units of resource S_2, and 860 available machines' hours, $s_1 = 1800,\ s_2 = 1600,\ s_3 = 860$). *What is the graphical interpretation of the initial basic feasible solution?* The initial solution graphically corresponds to vertex O=[0;0] of the feasible region (Figure 3).

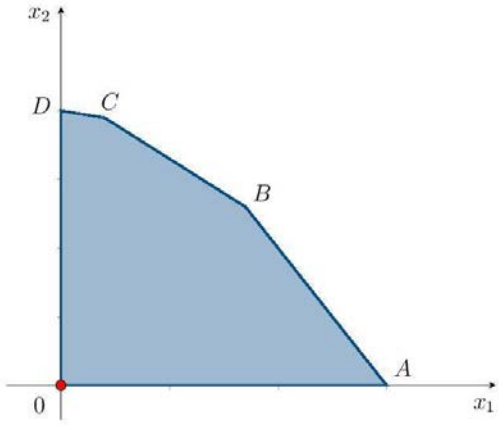

Figure 3 Initial basic feasible solution

What is the value of the objective function for the initial solution? Is it possible to increase this value by modifying the production plan (using a different feasible basic solution)? Is the obtained initial solution optimal? What is the meaning of the coefficients of the objective function? To determine whether the obtained solution is optimal, it is neccessary to assess if the value of the objective function $z(x_1, x_2) = 3x_1 + 4x_2 = 0€$ is maximized. Let's analyze the objective function $z = 3x_1 + 4x_2$. The coefficients of the function are non-negative, where one unit of product P_1 yields a profit of 3€ and one unit of product P_2 yields a profit of 4€ to the firm. Therefore, it is necessary to modify the production plan by introducing either product P_1 or product P_2 to increase the firm's profit (the value of the objective function). *Which product, not currently in the production plan, will yield a higher increase in profit?* By comparing the positive coefficients of the objective function (the unit profit from producing products P_1 and P_2), it was found that introducing the production of product P_2 will be more advantageous in terms of maximizing profit.

What is the maximum quantity of product P_2 that can be produced? The highest possible quantity of product P_2 should be produced. However, the available resource quantities limit the production. *Which resource has the most significant impact on the production of product P_2? How many products P_2 can be produced with the available quantity of resources and machines' capacity?* Let's examine each resource individually. There are 1800 units of resource S_1 in stock, and producing one piece of product P_2 requires 3 units of resource S_1. Therefore, 1800/3=600 pieces of product P_2 can be produced by using the available quantity of resource S_1. As for resource S_2, 1600/4=400 pieces of product P_2 can be made. The machines' hours M allows to produce 860/2=430 pieces of product P_2. The resource limiting production the most is the quantity of resource S_2, which determines that a maximum of 400 pieces of product P_2 can be produced.

How can the amount of manufactured product P_2 be expressed? Resource S_2 will be completely depleted, and thus the second inequality in the system (3) will be satisfied as an equation. The vector corresponding to the leaving variable s_2 will be replaced by the vector corresponding to the entering variable x_2 in the new production plan. Therefore, for the new basic variable x_2, the following condition holds

$$x_1 + 4x_2 + s_2 = 1600,$$
$$x_2 = 400 - \frac{1}{4}x_1 - \frac{1}{4}s_2. \quad (6)$$

How do the inventory of resource S_1 and machines' capacity M change through the production of product P_2? Since the production of product P_2 requires not only resource S_2 but also consumes resource S_1 and machines' hours M, the values of the remaining basic variables s_1 and s_3 are modified accordingly. Therefore, using equations (5) and (6), we obtain

$$s_1 = 1800 - 6x_1 - 3(400 - \frac{1}{4}x_1 - \frac{1}{4}s_2),$$
$$s_1 = 600 - \frac{21}{4}x_1 + \frac{3}{4}s_2, \quad (7)$$
$$s_3 = 860 - 2x_1 - 2(400 - \frac{1}{4}x_1 - \frac{1}{4}s_2),$$
$$s_3 = 60 - \frac{3}{2}x_1 + \frac{1}{2}s_2. \quad (8)$$

How can the current production plan be determined? How is the solution of a transformed system of linear equations acquired? Since the vectors corresponding to variables x_1 and s_2 are not in the basis (not included in the production plan), their values are chosen to be zero (no production of product P_1, and complete depletion of resource S_2). Therefore, the obtained values of the basic variables are as follows: $x_2 = 400,\ s_1 = 600,\ s_3 = 60$. Hence, when producing 400 pieces of product P_2, resource S_2 will be completely depleted. Resource S_1 will be consumed, leaving 600 unused units in stock. The remaining available machines' hours will be 60.

What is the graphical interpretation of the obtained solution? The entering base variable determines the direction of the displacement towards a new vertex of the feasible region. As x_2 is the entering variable, the

displacement is carried out by the OD-edge to reach the D-vertex (Figure 4).

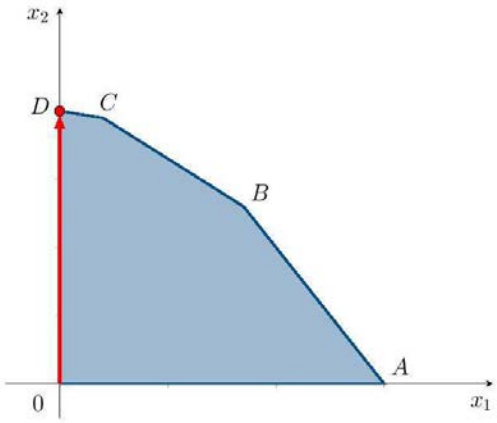

Figure 4 A new basic feasible solution

How will the profit be changed for the current production plan? Since the objective function obtains the form

$$z = 3x_1 + 4(400 - \frac{1}{4}x_1 - \frac{1}{4}s_2),$$
$$z = 1600 + 2x_1 - s_2, \qquad (9)$$

for $x_1 = 0$, $s_2 = 0$ (non-basic variables), the total profit will be $z = 1600$€.

By the simplex method [13], the initial tableau Table 2 is changed into Table 3, which is in accordance with the obtained relations (6), (7), (8), and (9).

Table 3 The second tableau of the simplex method

Base	x_1	x_2	s_1	s_2	s_3	z	b_i
s_1	$\frac{21}{4}$	0	1	$-\frac{3}{4}$	0	0	600
x_2	$\frac{1}{4}$	1	0	$\frac{1}{4}$	0	0	400
s_3	$\frac{3}{2}$	0	0	$-\frac{1}{2}$	1	0	60
z	-2	0	0	1	0	1	1600

Does the obtained solution optimize the objective function? Is profit 1600€ maximal? How does the profit corresponding to basic variables change? From the expression of the objective function (9), the modified profit for product P_1 and resource S_2 can also be determined. By introducing product P_1 into production and selling one unit of product P_1, the profit would increase by 2€. Including the vector corresponding to variable s_2 into the basis (to avoid completely depleting resource S_2), the value of the objective function would decrease by 1€. Since there is still a positive coefficient in the modified objective function, the obtained solution is not yet optimal. *What non-basic variable should enter the basis to maximize the obtained profit?* By changing the production plan, introducing product P_1 into production, the firm's profit can increase.

Why is a unit profit of non-basic variables changed? Interestingly, the original unit profit for product P_1 was 3€, but in the modified objective function it is 2€. This is due to the effect of changing the use of resources. The decrease is caused by the fact that when producing one unit of product P_1, the production quantity of P_2 products has to be reduced (due to insufficient capacity of resource S_2). Producing one unit of product P_1 consumes 1 unit of resource S_2, which is then missing in the production of P_2 products, and thus the number of products with a profit of 4€ needs to be reduced. To produce one unit of product P_2, 4 units of resource S_2 are needed. Therefore, the production of product P_2 needs to be reduced by 1/4 unit for each unit of product P_1 produced. The modified unit profit from one unit of P_1 is reduced by 1/4 of the profit from one unit of product P_2, which is $3 - \frac{1}{4} * 4 = 2$€.

How does the basis change? What will be the new production plan of the firm? By entering the vector corresponding to variable x_1 into the basis, which increases the value of the objective function, one vector corresponding to the existing variable leaves the basis. *How can the resource which limits the production of product P_1 the most be determined? What resource will also be completely depleted by new production?* The resource which limited the production of product P_1 the most is determined by calculating the ratios of modified available resources to positive modified technological coefficients (see them in equations (6), (7), and (8)). In some cases, the modified technological coefficients may become zero or even negative. In these cases, the ratios will not be calculated. (Dividing by zero is not possible, and if the technological coefficient is negative, the corresponding resource will not limit the introduction of the product into production. By introducing such a product into the production plan, resource will not be depleted further, but rather an increase in the available quantity of resource will occur.) The following ratios are acquired

$$\text{for } x_2: \frac{400}{\frac{1}{4}} = 1600,$$
$$\text{for } s_1: \frac{600}{\frac{21}{4}} = \frac{800}{7} \approx 114.3,$$
$$\text{for } s_3: \frac{60}{\frac{3}{2}} = 40.$$

The production of product P_1 is the most limited by the machines' capacity M. Therefore, the vector corresponding to variable s_3 is leaving the basis, while the vector corresponding to variable x_1 is entering the basis. *How can the quantity of manufactured product P_1 be determined?* Since (8) is the limiting constraint, it can be written in an equivalent form

$$\frac{3}{2}x_1 = 60 + \frac{1}{2}s_2 - s_3,$$
$$x_1 = 40 + \frac{1}{3}s_2 - \frac{2}{3}s_3. \qquad (10)$$

How are the expressions for determining the remaining basic variables x_2 and s_1 modified? The found expression (10) of basic variable x_1 allows to determine, using (6) and (7), the expressions of the other basic variables

$$x_2 = 400 - \frac{1}{4}(40 + \frac{1}{3}s_2 - \frac{2}{3}s_3) - \frac{1}{4}s_2,$$
$$x_2 = 390 - \frac{1}{3}s_2 + \frac{1}{6}s_3.$$
$$s_1 = 600 - \frac{21}{4}(40 + \frac{1}{3}s_2 - \frac{2}{3}s_3) + \frac{3}{4}s_2,$$
$$s_1 = 390 - s_2 + \frac{7}{2}s_3.$$

What is the next feasible solution to the solved problem? Which variables are equal to zero? If the non-basic variables are equal to zero again ($s_2 = 0,\ s_3 = 0$, that means resource S_2 and machines' hours M are fully depleted), the new values for the basic variables are obtained. The new feasible solution is $x_1 = 40, x_2 = 390, s_1 = 390$.

What is the modified profit of the firm? How is the value of the objective function changed? The value of the modified objective function is determined, using (9) and (10), by the expression

$$z = 1600 + 2(40 + \frac{1}{3}s_2 - \frac{2}{3}s_3) - s_2,$$
$$z = 1680 - \frac{1}{3}s_2 - \frac{4}{3}s_3. \qquad (11)$$

When $s_2 = 0,\ s_3 = 0,$ then the modified firm's profit will be 1680€.

Is the acquired solution optimal? Can another solution for which the value of the objective function is higher be found? Let's analyze the modified objective function (11). The modified coefficients in the objective function are negative or zero, so introducing vectors corresponding to variables s_2 and s_3 into the basis would decrease the profit (for one unit of resource S_2, the loss would be 1/3€, and for one unit of machines' hours M, the loss would be 4/3€). Therefore, the determined solution $x_1 = 40, x_2 = 390, s_1 = 390,\ s_2 = 0,\ s_3 = 0$ is optimal. This implies the production plan for the firm with the highest profit. The firm will produce 40 pieces of product P_1 and 390 pieces of product P_2. Resource S_2 and the processing time on machines' M will be fully utilized. Resource S_1 will remain unutilized with a remaining inventory of 390 units.

How can the optimal solution be graphically interpreted? A new displacement by DC-edge is made, up of C-vertex (Figure 5). At this point, the process ends. Vertex C is the optimal solution to the problem.

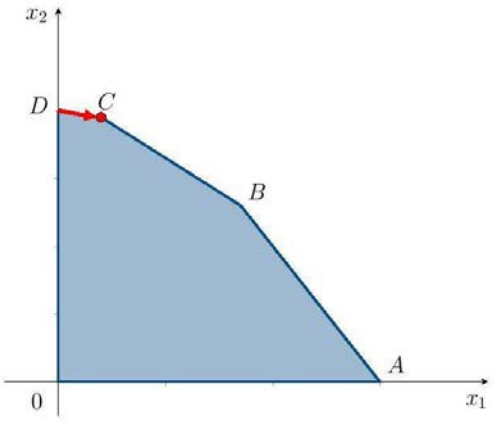

Figure 5 Optimal solution

Using the simplex method [13], the transformed tableau has the form of Table 4. Modified technological coefficients correspond to coefficients in the expressions of variables x_1, x_2, s_1, and the objective function z.

Table 4 The third tableau of the simplex method

Base	x_1	x_2	s_1	s_2	s_3	z	b_i
s_1	0	0	1	1	$-\frac{7}{2}$	0	390
x_2	0	1	0	$\frac{1}{3}$	$-\frac{1}{6}$	0	390
x_1	1	0	0	$-\frac{1}{3}$	$\frac{2}{3}$	0	40
z	0	0	0	$\frac{1}{3}$	$\frac{4}{3}$	1	1680

3 Conclusions

Logistics is the process of planning, organizing, and managing the movement of goods and raw materials in the supply chain. Currently, as new technologies change what logistics work entails, it is more important than ever to help students develop their critical skill set. The combination of critical-thinking skills and experience aids in a logistics professional's ability to anticipate and visualize processes from start to finish to optimise supply chain settings. It is challenging to find professionals who understand data and its role in logistics planning. Data is the key to making the right decisions, so the ability to analyze data and processes is the basis of education. This means solid knowledge of mathematics is very important. An essential part of good logistics flow is team management. Organizational skills are the requirements of a logistics manager. Teamwork is a vital component of any supply chain management system, as each role in these processes complements one another. Developing interpersonal skills such as patience, empathy, and active listening can help communicate ideas more effectively.

In the context of the rapid advancement of information technology, the educational process faces new and

challenging tasks. Current university students are living under the pressure of an enormous amount of information being pushed onto them in varying quality. The easier accessibility of information conflicts with students' ability to select relevant sources and content based on critical thinking. Therefore, it is essential for students not to be only passive recipients of predetermined algorithmic procedures but to be active in the learning process. It is as well equally important to be able to analyze causal relationships and think about the sequence of steps while solving the problems. An active approach helps them also learn how to communicate properly, recognize errors in their opinions, argue and defend their solutions correctly.

The article aims to highlight the possibilities of a constructivist approach in teaching linear programming problems in the field of operational research and logistics in the context of university education. This approach provides a suitable environment for the development of students' critical thinking. Within solving the optimization problem two mathematical methods were connected and the algorithm was analyzed in detail step by step. The integration of multiple approaches helps students to see the problem in context and teaches them different ways how to analyze the problems and find solutions. This allows them to develop unconventional methods and approaches to problem-solving. Students acquire solution frameworks that they can subsequently apply to solve other problems. Understanding and identifying strengths and weaknesses in the used methods enables students to use the methods correctly and choose them effectively for solving problems.

The young generation will soon face the challenge of not succumbing to artificial intelligence and maintaining information technology at a level that serves humanity. Therefore, seeking new educational approaches that help strengthen students' skills of critical thinking is a very important necessity.

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Application of a time series to analyse the evaluation of road traffic accidents in Slovakia

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Keywords: road traffic accident rate, indicators of traffic accident rates, time series, ETS method, forecasting.
Abstract: Road traffic accidents represent an important part of the road traffic system. In many cases, they may lead not only to damage to vehicles and property, but also serious injuries or even death of road traffic participants. The prevalence of road traffic accidents and the related fatality rates in a country is a significant indicator of the maturity of that country and its inhabitants. The purpose of this article was to review the prevalence of road traffic accidents and fatality rates in the Slovak Republic over the period from 2009 to 2022. The analysis was conducted by applying basic statistical methods and a time series analysis (exponential smoothing method – ETS). The ETS is a method used for forecasting a time series univariate. The focus of this method is on three time series components (error E, trend T and seasonal S), while defining how the individual components interact. The results of the analysis indicated a positive, i.e. a falling trend in road traffic accident rates, according to the numbers of persons killed/injured in road traffic accidents in Slovakia. Compared to 2009, in 2020 there was a decrease in the number of road traffic accidents by almost 54%. In 2022, the number of fatalities decreased by almost 30% compared to those in 2009. The modelling also involved a forecast of the number of persons killed/injured in road traffic accidents for a period of 5 years.

1 Introduction

Mobility and transport are of high importance for the society. Although they provide many benefits, they are also associated with a number of drawbacks, such as the greenhouse emissions, noise, water and air pollution, as well as traffic jams and accidents. Road traffic accidents are events which result not only in injuries or death of road traffic participants, but also in material damage.

According to the World Health Organization, approximately 1.3 million people die every year as a result of road traffic crashes. Other 20–50 million people suffer non-fatal injuries, while many of the injured become disabled [1]. Globally, almost 3,700 people die on roads in accidents involving cars, buses, motorcycles, bicycles, trucks or pedestrians. More than half of those killed in the crashes are pedestrians, cyclists and motorcyclists [2]. According to the information published by the European Commission, in 2022, around 20,600 people were killed in road crashes in the EU countries, which is a 3% increase compared to 2021. This was caused by the recovery of the traffic intensity after the pandemic [3].

Over the last few decades, the road traffic safety in the European Union (EU) countries has significantly improved thanks to the considerable efforts exerted at the European, regional and local levels. In years 1991–2017, and particularly after 2000, the EU witnessed a significant improvement in the field of road traffic safety in terms of the number of fatalities and injuries. Over a shorter period, in years 2001–2010, the number of deaths on roads in the EU decreased by 43% and since 2010 by additional ca 20% [4]. Nevertheless, the number of persons killed on roads across the EU has not significantly changed over the last 5 years.

The road traffic accident rate is an important indicator of the quality of the transport infrastructure and the relevant legislation; it also reflects the awareness of the road traffic rules among the inhabitants of a particular country. In the European Transport Policy, the EU has laid down ambitious long-term goals for the road traffic safety. The EU representatives issued a resolution [5,6] that is aimed at increasing the road traffic safety and approaching the zero-fatality rate on the EU roads by 2050 (Vision Zero). The resolution includes limiting the speed in residential areas to 30 km/h, implementing the zero-tolerance approach regarding the use of alcohol and other addictive substances while diving, and implementing the state-of-the-art safety features both in roads and vehicles. According to [6], the Vision Zero will be implemented through influencing the attitudes of road traffic participants, taking targeted measures aimed at high-risk road participants, creating the safe traffic area, increasing the safety of motor vehicles, ensuring fast and efficient post-crash medical care, and applying modern technologies. According to [7], there are several causes of road traffic accidents. The key ones include a speed limit violation, drunk driving, driving without a break, not paying attention to the traffic, poor quality of roads, bad weather and so on. Kurakina et al. [8] stated that the key indicator of road traffic safety is the absence of road traffic accidents. In a paper [8], authors discussed the methods for forecasting the road accident rates using the Driver-Vehicle-Road-Environment (DVRE) system. Darwish et al. [9] deal with the key factors that contribute to traffic accidents in Jordan, based on a dataset obtained from the Traffic Institute's 2021 database.

Vilaça et al. conducted a statistical survey with the aim of assessing the severity of road traffic accidents and identifying the correlations between the accidents and the road traffic participants [10]. The output of the study was a recommendation to improve the road safety standards and adopt more policies regarding the safety of transport. Authors [11] analysed 20 influential factors of road traffic crashes (e.g. drivers' behaviour and driving experience, vehicles' safety condition, vehicles' purpose, road lighting quality, road surface condition, roadside protection facilities, road terrain etc.). The key factors were identified by applying the factor analysis.

Olszewski et al. [12] examined the factors affecting the risk of death of pedestrians, cyclists, motorcyclists and moped riders in seven EU countries using the data from the CARE database. The results were presented as odds ratios of fatal accident outcomes in different countries under specific circumstances compared to the reference conditions. The safety of traffic was also discussed in [13]; authors applied the data mining algorithms, including the basket analysis, to analyse the road traffic accident rates in Hampshire, England. The modelling of the road traffic accidents in Addis Ababa by means of the adaptive regression trees was presented in [14].

Severity of road traffic accidents was examined in [15]. The decision trees and the artificial neural networks were applied to identify three main factors affecting fatality rates for road traffic accidents: not using a seat belt, drunk driving, and inappropriate lighting conditions on roads. Authors Chand et al. [16] provided a review of the sources of data on road traffic accidents, as well as the data analysing techniques and various algorithms that are used for forecasting the road traffic accidents. Authors Sze and Wong [17] presented the assessment of the risk of pedestrians suffering an injury in a road traffic accident and the analysis of the factors that contribute to fatalities and severe injuries. The correlations between the probability of death and a serious injury and all the influential factors were identified by applying the binary logistic regression.

Authors Lavrenz et al. [18] presented a review of the current state of the art regarding the use of time series models in the research into transport safety and discussed some of the basic techniques and considerations concerning the conventional time series modelling. The article [19] deals with the road traffic fatalities in India in years 1967–2015, analysed by applying the time series and the ARIMA model. Based on the forecasted numbers of fatalities in road traffic accidents, authors expect a rising trend in the number of fatalities in road traffic accidents in India over the next 10 years. Greibe [20] described the accident prediction models that are capable of the most accurate forecasting of fatality rates for urban junctions and road links. The models were based on data for 1,036 junctions and 142 km of road links in urban areas. The generalised linear modelling techniques were used to relate the accident frequencies to the explanatory variables. Jasiuniene et al. [21] conducted the evaluation of road traffic accidents on road links and junctions in Lithuania in years 2014–2018, while the road traffic accident rates were forecasted by applying the empirical Bayes method. The authors also recommended collecting detailed information on the geometrical and operational characteristics of roads that affect the risk of serious accidents.

In the article [22], the prevalence of road traffic accidents and the amounts of the collected road tax in the Czech Republic is discussed. The authors found out that despite a stable increase in the amount of the collected road tax over the years, the accident rates gradually decrease; however, that decrease is not as intensive as the increase in the collected road tax. They stated that the collected money, which should be spent on resolving the problems with the road network (road traffic safety, repairs, construction of new roads etc.), was not used exclusively for those purposes. Authors Stefko et al. [23] modelled the damage to the property and the accidents with injuries and fatalities that had happened in the Slovak Republic. They concluded that the accidents with fatalities and injuries strongly affect the property damage. They also pointed out that the expressways significantly reduce the rates of accidents in which there are fatalities. Road traffic accidents in Slovakia that happened in years 1999–2009 were analysed by authors Kalašová and Krchová [24]. They claimed that with the use of new, modern and smart systems and applications, the transport safety may be improved. The forecasts of road traffic accident rates in Poland and Slovakia, as well as the evaluation of how the COVID-19 pandemics affected their trend, were presented in [25]. The accident rates were forecasted by applying selected time series models. Authors pointed out that the pandemics caused a decrease in the road traffic accident rates in Poland by 31% and in Slovakia by 33%. Gorzelańczyk [26] analysed the number of road traffic accidents in Poland relative to the weekdays when they happened. The data was used to forecast the accident rates by 2024 based on the time series.

The road traffic safety in the Slovak Republic relates not only to the road traffic safety at the national level, but also on the European level. The key indicator of the traffic accident rates in the country is the total number of road traffic accidents and the number of persons killed in road traffic accidents. The purpose of this article was to analyse the road traffic accident rates and the number of persons killed/injured in road traffic accidents in Slovakia. The result of the analysis was the modelling of the prevalence of the number of deaths with the use of a time series and the forecasting of the number of deaths for the next 5 years.

2 Methodology

2.1 Basic terms

Slovakia (the Slovak Republic) is an inland country located in the Central Europe (Figure 1) and a member of the European Union since 2004. The territory with the total surface area of 49,035 square km is inhabited by ca 5.45 million inhabitants. Bratislava is the capital city.

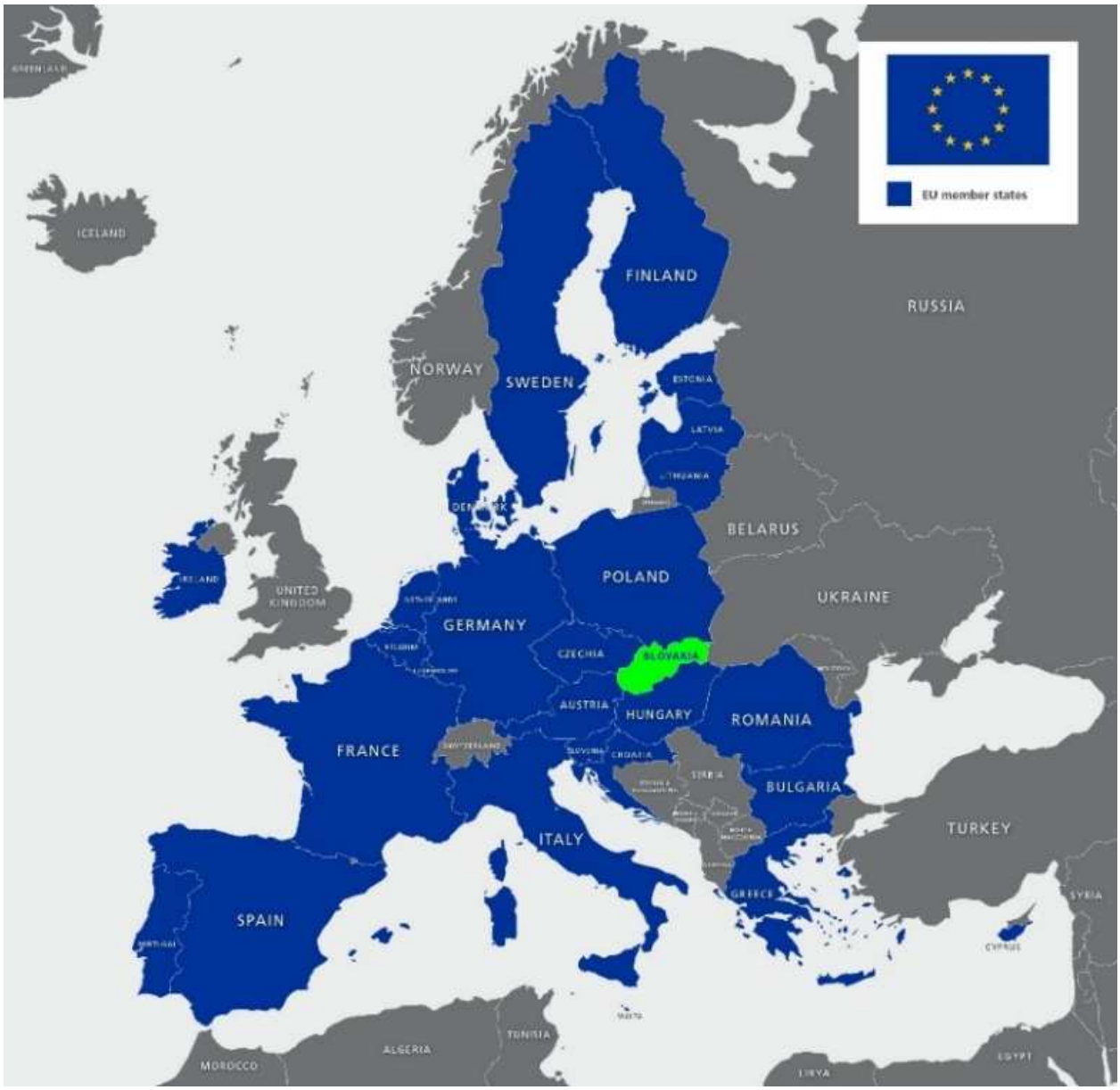


Figure 1 Location of Slovakia in the EU [Base map © maproom.net]

The road infrastructure in Slovakia consists of highways, expressways and Class I, II and III roads. The current state of the road infrastructure is characterised by a relatively dense network of roads, but with only a small proportion of highways and expressways. In 2020, the road network in Slovakia consisted of 18,130 km of roads and highways, while the highways represented 521 km [27]. 112 km of new highways and expressways are expected to be built in Slovakia by 2030.

According to [28], a traffic accident is an event caused by a moving vehicle in the road traffic with a consequence of death, injury or property damage, regardless of whether it is classified as a crime or an offence and whether it is subject to the proceedings in court or before the Penal Commission of the Traffic Inspectorate. Such events include the traffic accidents that happen at places with a limited road access (e.g. field roads and forests roads, roads in factories, in yards etc.) [28].

Severity of road traffic accidents is categorised depending on whether an accident resulted only in damage to property, or the accident participants suffered a minor or serious injury or even death. Pursuant to Act No 433/2010 Coll., supplementing Act No 513/2009 Coll. (on Road Traffic and on Amendment and Supplementation to Certain Acts), a death (killed person) means any person that is killed in an accident or dies within 30 days due to an injury caused in an accident. The number of deaths only includes the persons who die due to an injury in a traffic

accident within 24 hours after the accident. An injured person is a person who has not died, but suffered an injury in an accident and needed a medical treatment. A seriously injured person is an injured person who is hospitalised for longer than 24 hours. A person with a minor injury is a person who has suffered an injury in an accident other than a serious injury, except for the cases when a single treatment is required without a need for any specialised treatment or a sick leave [29].

As a full-value member of the EU, the Slovak Republic (SR) became a member state of the Third global ministerial conference on road traffic safety, held in Stockholm, Sweden, in February 2020, at which a new action decade was announced with the goal of increasing the safety of road traffic by 2030 [30]. In Slovakia, two medium-term strategic goals were set for the period of 2021–2030 and one long-term strategic goal was determined for the period by 2050. The first medium-term strategic goal is to halve the number of fatalities in road traffic accidents in the SR by 2030 compared to the number of fatalities in the reference year 2020. The second medium-term strategic goal is to halve the number of serious injuries in road traffic accidents in the SR by 2030 compared to the number of serious injuries in the reference year 2020. A long-term strategic goal (Vision Zero) is to reduce the number of fatalities and the number of serious injuries in road traffic accidents in the SR to zero by 2050. For the purpose of accomplishing those strategic goals, certain measures were defined for five different areas: a human factor; the risk groups of road traffic participants; road safety; vehicles and technologies; and post-crash care.

2.2 Statistical methods

The assessment of the prevalence of road traffic accidents in Slovakia was based on the data collected by the Ministry of Interior of the Slovak Republic [31].

The analysis and the assessment were carried out by applying basic statistical methods and a time series analysis. A time series means a series of observations that are comparable in their nature and location, arranged chronologically from the past to the present [32]. A time-series forecast is a quantitative forecast of the future values of a time series based on the assumption that the current development will continue in future without any changes.

In this article, the prevalence of road traffic accidents was forecasted by applying the ETS (ExponenTial Smoothing) method. The ETS is a forecasting method used for predicting a future value based on the existing (historical) values by using the exponential smoothing algorithm [33]. Hyndman [32] stated that the forecasts created with the use of the exponential smoothing methods are the weighted averages of the previous observations, while the weights exponentially decrease as the observations get older. In other words – recent observations are given relatively more weight in forecasting than the older observations. Those methods therefore enable generating reliable forecasts in a short period of time and for a wide range of time series. Such an advantage makes them very important for industrial applications. The ETS method is based on all previous observations. Their weights exponentially decrease as they become less recent. Every model consists of three components: Error, Trend and Seasonal. The Error component may be characterised as “Additive=A” or “Multiplicative=M”. Trend may be described as “None=N”, “Additive=A”, “Additive damped=Ad”, “Multiplicative=M” or “Multiplicative damped=Md”. The Seasonal component may be “None=N”, “Additive=A” or “Multiplicative=M”. There are 15 forecasting models with additive errors and 15 models with multiplicative errors. Based on the assumption of normality of the error term (Shapiro-Wilk test of normality), the ETS model can be estimated via the maximisation of likelihood. The time-series forecasting model was created with the use of the R package forecast and the ets() function [34]. The methodology is fully automatic. The only required argument for ets is the time series. With regard to choosing the most appropriate model, the conventional approach includes the application of all models and then choosing the best model based on the information criterion. The best model may be identified using the Akaike's Information Criterion (AIC). A general rule is that the lower the AIC value, the better the model is compared to a model with a higher AIC value.

3 Result and discussion

This investigation was aimed to analyse the prevalence of road traffic accidents and the number of persons killed/injured in road traffic accidents in the Slovak Republic in the period from 2001 to 2022.

3.1 Basic terms

Based on the available data, 685,984 road traffic accidents were reported in Slovakia in the period of 2001–2022. The average annual number of road traffic accidents was almost 21,182. A significant decrease in this number was observed in 2009 – from 59,008 reported accidents (in 2008) to 25,989 reported accidents (in 2009). It was caused by changes in legislation.

A graphical representation of the prevalence of road traffic accidents in Slovakia over the analysed period of 2001–2022 is shown in Figure 2. The red line represents the average annual number of road traffic accidents in the whole period of 2001–2022 (31,181.1). The red dashed line represents the average annual number of road traffic accidents in the period of 2009–2022 (14,856.4), representing a 53.6% decrease. In the long term, there is a falling trend in road traffic accidents in Slovakia.

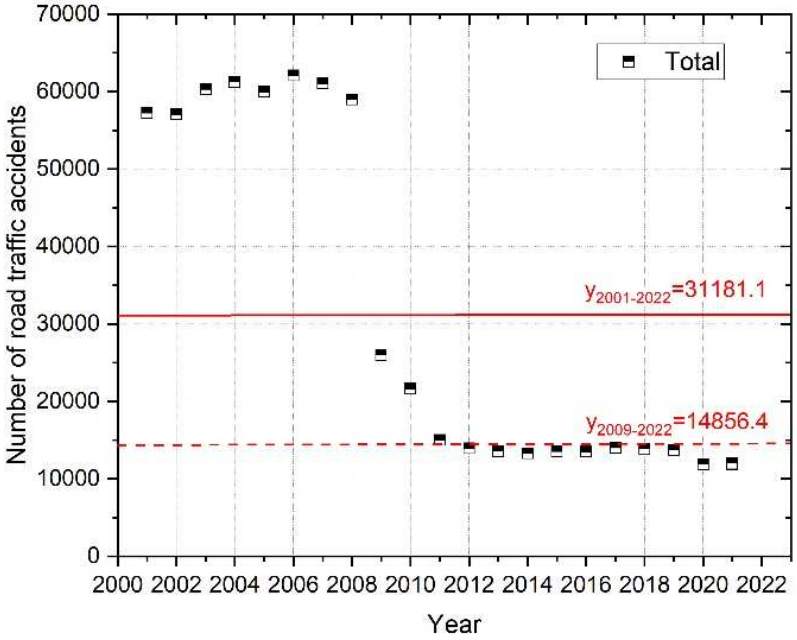


Figure 2 Prevalence of road traffic accidents in Slovakia (2001–2022)

The basic numerical characteristics of the locations of and variability in road traffic accidents are listed in Table 1.

Table 1 Numerical characteristics of road traffic accident rates in Slovakia

Period	Number	Arithmetic mean	Minimum value	Maximum value	Range	Standard deviation
2001–2022	22	31,181.1	11,875	62,070	50,195	22,350.1
2009–2022	14	14,856.4	11,875	25,989	14,114	3,983.5

Based on the time-series characteristics, it is possible to conclude, for example, that in 2003, compared to 2002, there was an increase in the number of road traffic accidents by 3,244 accidents. The pace at which the number of road traffic accidents increased in 2003, compared to 2002, is 5.69%, representing almost a 6% increase. In 2020, there was a significant decrease (by almost 14%) in road traffic accidents compared to 2019 (a decrease by 1,866 road traffic accidents), which may have been caused by a number of factors, including the lower mobility of the population due to the COVID-19 pandemics. With year 2001 being chosen as the reference year, the 2009 figures represent almost a 54.6%, decrease in the number of road traffic accidents, while the 2021 data constitute as much as a 78.9% decrease. With 2009 as the reference year, in 2022 there was a decrease in the number of road traffic accidents by 13,924 accidents – representing a 53.6% decrease.

3.2 Developments in selected indicators of road traffic accident rates in Slovakia (2009-2022)

Due to a significant decrease in the number of accidents since 2009, compared to the 2001 data, selected indicators of changes in the road traffic accident rates in Slovakia (the number of fatalities and the number of injuries) were analysed in relation to the period since 2009.

3.2.1 Developments in the number of fatalities in road traffic accidents (2009-2022)

The available data indicated that there were 3,728 fatalities in road traffic accidents reported in Slovakia in years 2009–2022. The average annual number of fatalities was almost 267. The results show that despite the reduced mobility of the population, caused by the COVID-19 pandemics, in 2020, the number of fatalities did not significantly decrease (the decrease was comparable to those of the previous periods). The basic numerical characteristics of the location of and the variability in the number of selected indicators are listed in Table 2. The focus of the analysis of changes in the number of persons killed in road traffic accidents included not only the total number of fatalities, but also the number of fatalities among cyclists and pedestrians, as well as the number of fatalities among drivers and passengers in cars and on motorcycles.

Table 2 Numerical characteristics of the number of persons killed in accidents (period 2009–2022)

Indicator (Number)	Number	Arithmetic mean	Minimum value	Maximum value	Range	Standard deviation
Drivers and passengers in cars and on motorcycles	2,503	178.8	142	231	89	29.1
Pedestrians	978	69.6	42	113	71	19.6
Cyclists	250	17.9	12	25	13	4.0
Total						
Fatalities (traffic accident participants)	3,728	266.3	223	347	124	44.3

A graphical representation of changes in the number of deaths in road traffic accidents in Slovakia over the analysed period of 2009–2022 is shown in Figure 3. In the period from 2009 to 2013, there was a significant decrease in the number of deaths, while particularly in 2013 the number of deaths reached the lowest value (223 persons), representing a 35.7% decrease compared to the value of the reference year 2009 (347 persons). A relatively sudden increase in the values that was observed in years 2014 and 2015 may be regarded as a negative phenomenon in the analysed period. However, after 2015, the curve of the numbers of deaths exhibits a slightly decreasing trend. In 2022, the number of deaths was 244, representing a decrease by 103 persons compared to the 2009 data (a 29.7% decrease).

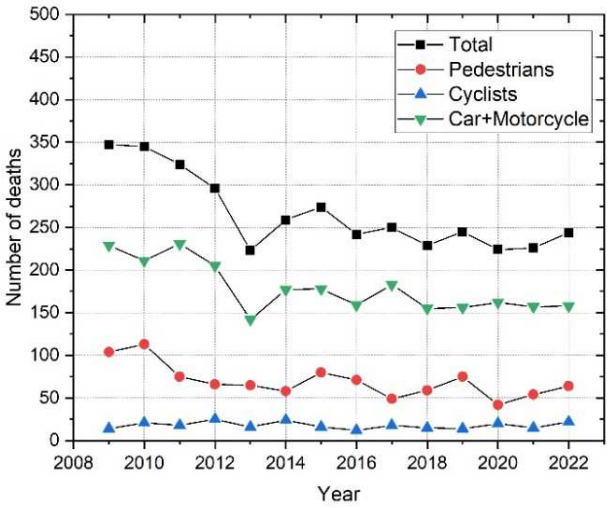


Figure 3 Numbers of deaths in road traffic accidents in Slovakia

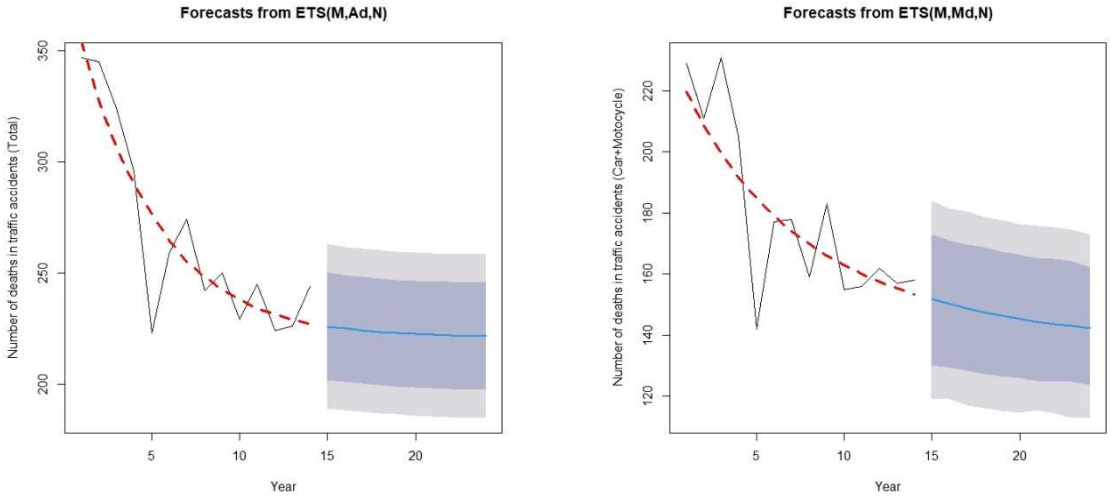
The number of persons killed in road traffic accidents was forecasted for the next period by applying the ExponenTial Smoothing method (ETS). Compliance with the data normality requirement was verified using the Shapiro-Wilk test of normality. The null hypothesis acceptance or rejection was based on a p-value. If the p-value equals to or is higher than the predetermined significance level α, then the null hypothesis is not rejected. The p-value was higher than α (α=0.05); therefore, the null hypothesis on normality was not rejected. The resulting time-series forecasting model consisted of three components: Error, Trend and Seasonal. Several different models were considered and subjected to a comparison by applying the AIC criterion. The best model was the model with the lowest AIC value (Table 3).

Table 3 List of ETS models of the forecast number of deaths (total)

ETS model	AIC	ETS model	AIC
M, M, N	135.1	M, N, N	134.0
M, Md, N	134.5	A, N, N	135.7
M, A, N	129.4	A, A, N	137.5
M, Ad, N	129.3	A, Ad, N	134.9

Note: M-multiplicative; A-Additive; N-None; Md-Multiplicative damped; Ad-Additive damped.

Apparently, the best model is the ETS(M,Ad,N) – a damped trend (Ad) with multiplicative errors (M) and no seasonality (N). The damping factor acquired a value of 0.8. A graphical representation of the original and the smoothed time series based on ETS is shown in Figure 4a. The graph shows a forecast of the number of deaths (Total) for the period of the next ten years. In addition to the point estimate of the forecast, prediction intervals were also created. The grey and blue fields show the 95% and 80% prediction intervals for the forecasts obtained from ETS.



a) *b)*

Figure 4 Developments and forecasts of a) the total number of deaths; b) the number of deaths in/on vehicles (car+motorcycle) in road traffic accidents in Slovakia

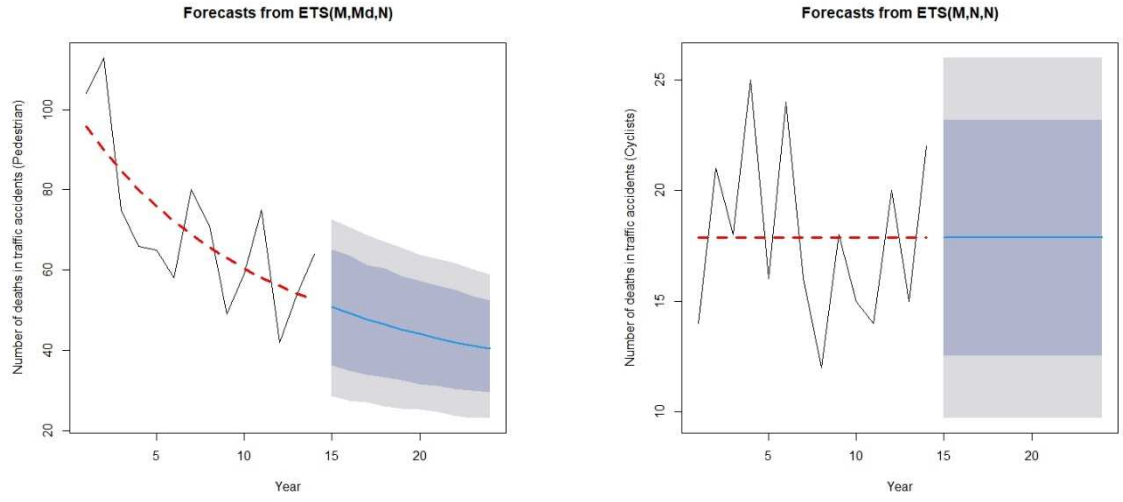
The forecast of the number of deaths in road traffic accidents in Slovakia for the period of the next 5 years and the prediction intervals for the best model ETS(M,Ad,N) are shown in Table 4.

Table 4 Forecasts of the number of deaths and the prediction intervals for the period of 5 years

Year	Forecast	80% Prediction interval		95% Prediction interval	
		Lower	Upper	Lower	Upper
2023	225.9	201.8	250.2	189.0	262.9
2024	224.9	200.8	249.0	188.1	261.8
2025	224.1	200.1	248.1	187.4	260.8
2026	223.4	199.4	247.4	186.7	260.1
2027	222.9	198.9	246.8	186.2	259.5

It may be stated that the number of deaths in road traffic accidents in Slovakia exhibits a slightly decreasing damped trend in the long run.

An analogical procedure was applied to the evaluation of the number of deaths in/on vehicles and among pedestrians and cyclists. Compliance with the data normality requirement was verified using the Shapiro-Wilk test of normality. The best model was chosen by applying the AIC criterion. In the following section, only the best models with the lowest AIC values are discussed. Figure 4b, Figure 5a and Figure 5b show the resulting best models and forecasts for the next period.



a) *b)*

Figure 5 Developments and forecasts of the number of deaths among a) pedestrians and b) cyclists in road traffic accidents in Slovakia

Apparently, the best model for the number of deaths in/on vehicles (car+motorcycle) and among pedestrians is the ETS(M,Md,N), i.e. a damped trend (Md) with multiplicative errors (M) and no seasonality (N). Based on the observations of the developments and forecasts of the number of deaths among cyclists, the best model is the ETS(M,N,N), which represents the simple exponential smoothing without a trend.

3.2.2 Developments in the number of injuries in road traffic accidents (2009-2022)

Based on the available data, a total of 93,617 persons injured in road traffic accidents were reported in Slovakia in years 2009–2022. The average annual number of injuries was almost 6,687. As much as 78,236 persons suffered minor injuries, representing almost 83.6% of the total number of injuries. The basic numerical characteristics of the locations of and the variability in the number of injuries (minor/serious) are listed in Table 5.

Table 5 Numerical characteristics of the number of injuries (period of 2009–2022)

Indicator (Number)	Number	Arithmetic mean	Minimum value	Maximum value	Range	Standard deviation
Minor injuries	78,236	5,588.3	4,462	9,274	2,664	767.3
Serious injuries	15,381	1,098.6	869	2,367	539	147.3
Total						
Injuries	93,617	6,686.9	5,373	8,534	3,161	897.7

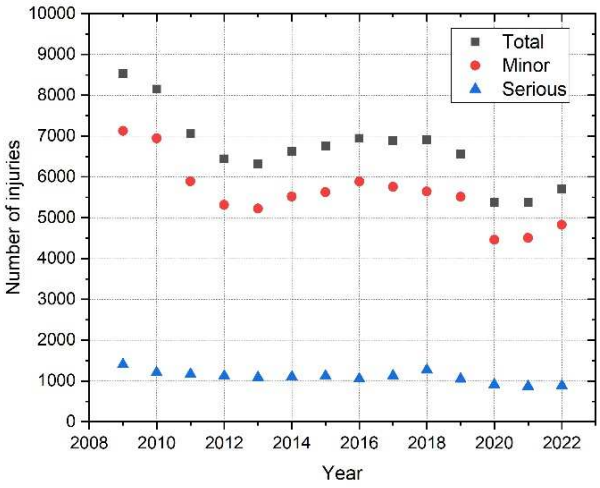


Figure 6 Developments in the number of injuries in road traffic accidents in Slovakia

A graphical representation of the numbers of persons injured in road traffic accidents in Slovakia over the analysed period is shown in Figure 6. The largest number of injuries was observed in 2009 (8,534 persons), while the lowest number was observed in 2021 (5,373 persons); compared to 2009, it represents a decrease by 3,161 persons (approximately a 37% decrease). Similarly to the previous case, there was a falling trend in the number of persons injured in road traffic accidents in Slovakia in the long run.

The number of persons with serious injuries in road traffic accidents exhibits a slightly falling trend over the period from 2009 to 2016. In years 2017 and 2018, there was an increase in the values of this indicator, while the 2018 value (1,272 persons) represents the maximum in the entire analysed period. Since 2019, the number of serious injuries has been exhibiting a falling trend. In 2022, the number of serious injuries was 882, representing a 37.4% decrease compared to the reference year 2009 (1,408 persons). Over the long term, the number of persons with minor injuries exhibits a falling trend and copies the trend of injuries (total). Considered the entire analysed period, the highest number of minor injuries was reported in 2009 (7,126 persons), while the lowest number was observed in 2022 (4,462 persons). In the period of 2014–2016, there was an increase in the number of minor injuries. In 2020, there was a significant decrease in the number of minor injuries compared to the previous year 2019 (5,515 persons) – a 19% decrease (decrease by 1,053 persons). Over the last two years 2021 and 2022, the number of minor injuries exhibited a slightly rising trend.

Figure 7 and Figure 8 show the graphical representations of the best models of the past and forecasted numbers of injuries (minor/serious) in road traffic accidents in the period of 2009–2022 by applying the ETS method. Compliance with the data normality requirement was verified using the Shapiro-Wilk test of normality.

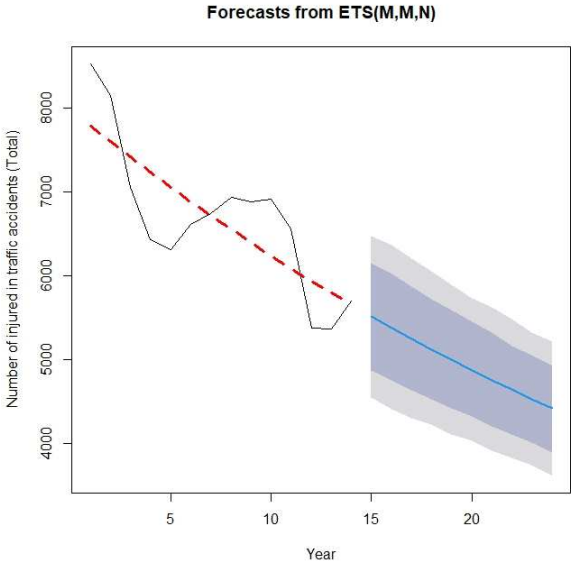
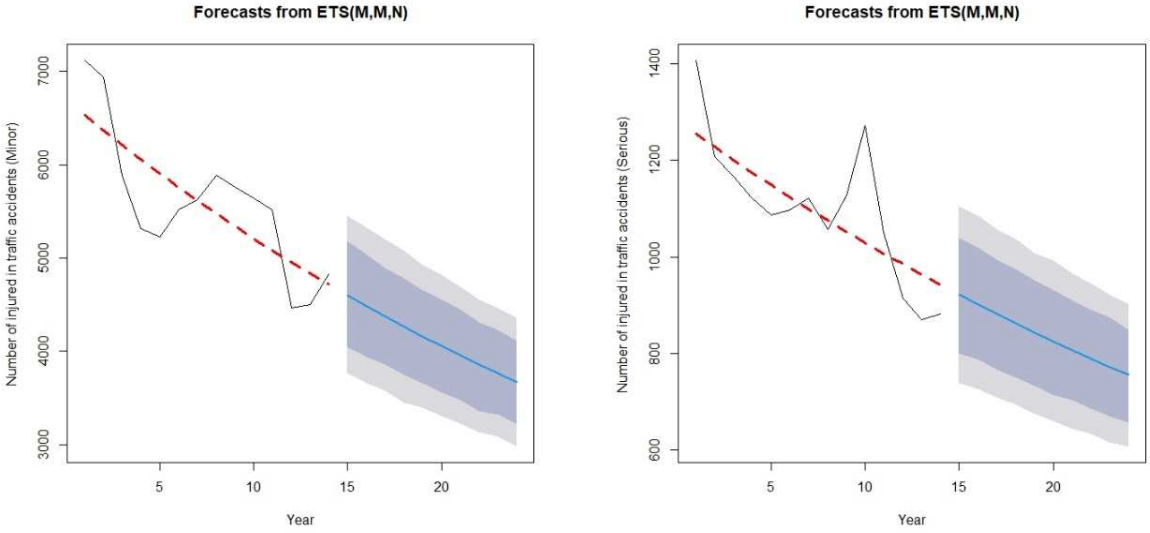


Figure 7 Developments and forecasts of the number of injuries (total) in road traffic accidents in Slovakia



a) *b)*

Figure 8 Developments and forecasts of the number of persons injured in road traffic accidents in Slovakia: a) minor injuries; b) serious injuries

It seems that in all of the cases the best model is the ETS(M,M,N), i.e. the exponential smoothing model with a multiplicative trend and error. The forecasted numbers of persons injured in road traffic accidents in Slovakia for the next 5 years, as well as the prediction intervals for the best model ETS(M,M,N), are shown in Table 6.

Table 6 Forecasts of the number of injuries and the prediction intervals for the next 5 years

Year	Forecast	80% Prediction interval		95% Prediction interval	
		Lower	Upper	Lower	Upper
2023	5,518.7	4,857.5	6,175.3	4,490.0	6,533.3
2024	5,384.4	4,750.0	6,027.5	4,423.6	6,356.7
2025	5,253.4	4,649.2	5,866.2	4,322.2	6,195.7
2026	5,125.6	4,534.1	5,711.0	4,212.6	6,034.3
2027	5,000.9	4,422.7	5,577.7	4,104.2	5,909.5

The number of persons injured in road traffic accidents in Slovakia forecasted for 2023 is 5,518.7. In the period from 1 January 2023 to 30 June 2023, there were 1,988 road traffic accidents reported with a total of 2,544 injured persons (380 serious and 2,164 minor injuries) and 107 fatalities.

4 Conclusions

The annual death toll from road traffic accidents in Slovakia is several hundreds of lives. Every year, there are also thousands of injuries and significant property damage is caused. In the National Strategy for years 2011–2020, the Slovak Republic laid down the main goal to halve the number of fatalities in road traffic accidents by 2020 compared to the number reported in 2010. In 2010, there were 345 deaths in road traffic accidents, while in 2020 there were 224 of them, representing a decrease by 121 persons. This means that the decrease represented only ca 35% and the main goal for 2011–2020 has not been accomplished.

Reducing the road traffic accident rates is very important from a societal point of view. It will result in higher safety on roads, which will consequently reduce the fatality rates, the costs of medical care of persons injured in accidents, the property damage, as well as the costs of removing the damage. A more recent medium-term strategic goal is to halve the number of persons killed in road traffic accidents in the SR by 2030 compared to that in year 2020. In 2020, there were 224 fatalities. This means that according to the target value, approximately 112 fatalities are predicted to happen in 2030. With regard to the forecast obtained from the model of the number of fatalities, which was created by applying the ETS method, there is a rising concern whether such a goal is feasible.

Despite the unaccomplished goals, there is a positive falling trend in the number of road traffic accidents, as well a falling trend in the number of persons killed or injured in road traffic accidents in Slovakia. The most frequent cause of accidents is a human failure. For this favourable trend of decreasing road traffic accidents or fatalities/injuries to continue, it is necessary, above all, to respect the traffic rules, conduct more frequent stop.

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Research of urban passenger transport in countries with a high Human Development Index
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Research of urban passenger transport in countries with a high Human Development Index

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Keywords: passenger traffic, gross domestic product, infrastructure, economic indicators, service quality improvements.
Abstract: The aim of this research is to investigate urban passenger transport in countries with a high human development index and establish a logical relationship between this index and the features of urban transport in developed countries worldwide. The study's methodology is based on economic and statistical approaches to the economy's main indicators. Mathematical modelling is used to obtain results on the influence of passenger traffic indicators on GDP. The study also assesses the role of regulators in this process. The study's results are interpreted based on the experience of the largest countries with the highest degree of interaction between these indicators. Conclusions are drawn regarding the need to develop preventive measures, taking into account the best international practices. The results and conclusions of this research are significant for public transport workers. They provide a practical opportunity to improve various aspects of their activities and the quality of service in the field of public urban transport.

1 Introduction

It is difficult to overestimate the importance of the transportation system for the economy of any state. In conditions of economic instability caused by internal economic and political contradictions, as well as from the standpoint of the impact of the global financial crisis, the public transport sector remains one of the most stable sectors of the economy, ensuring the stability of the functioning of the economy of any state [1]. Therewith, the potential of the transport industry is so high that there are a great number of opportunities for its development. The current global fleet of registered automobile rolling stock is about 600 million units, including 86% of passenger cars, 13% of trucks, and only 1% of buses. The largest number of rolling stocks is concentrated in Europe (40%), America (32%), and Asia (21%). In general, the short-term prospects for the development of road transport in the world are fully correlated with long-term forecasts, which practically guarantee a fairly moderate growth rate of the fleet and road network for the period up to 2030 [2]. The progress in the development of road transport in modern countries with a high Human Development Index (HDI) will be expressed in the qualitative improvement of vehicles and the development, improvement, and implementation of highly efficient technological processes that contribute to reducing the burden on the environment.

It should be considered that the gradual introduction of environmentally friendly fuels into the practice of modern urban transport is quite realistic. The improvement of surface types of roads will continue quite quickly, increasing their capacity while increasing road safety. As for the distribution of vehicles worldwide, it is expected that the relative share of large countries will decrease due to the faster growth in the number of vehicles in developing countries, primarily in China [3]. In the future, it is expected to increase the fleet of trucks, especially in Europe, by about 1.5-3% annually until 2030. Nearly the same amount is projected to increase the total length of highways in the developed countries of the world. Industrialised countries will continue to dominate in terms of the quality of vehicles and roads until 2030. In other countries, the rapid increase in the number of vehicles and the length of roads will be characterised by qualitative indicators. It is difficult to overestimate the importance of passenger transport for the economic development of the country; this is the reason for the relevance of the subject

of this research. Nowadays, the transport system is the "circulatory" system of the economy. The development of transport is an indispensable condition for the functioning of the economy and ensuring a high quality of life for the population [4]. The specific features of transport as an economic industry are that it does not manufacture products itself but only takes part in their creation. Transport provides production with raw materials and equipment and delivers finished products to the consumer. The gross domestic product (GDP), which is the main indicator of the country, depends on the development of transport.

The problems of the development of the transport system of any state become problems of its economic development and prevent the creation of full-fledged living conditions in society since the quality of transport system functioning is directly related to the standard of living of any society. The development of transport is directly related to the human development index since the problems of transport network development cause a decrease in the overall standard of living in the country, which, in turn, negatively affects the quality of life of individual citizens [5]. Thus, the existence of a clear relationship between the level of transport system development in the state and the standard of living in the country and in society in general largely determines the prospects for the development of both the state itself and its transport system, since the relationship between these two components determines the prospects for improving the standard of living in society and the opportunities for increasing the HDI in a particular state in general.

2 Materials and methods

The methodology of this study is based on economic and statistical approaches to the interaction of the main indicators of the economy, based on which the results of mathematical modelling of the influence of the interaction of passenger traffic indicators on GDP are obtained and an assessment of the role of regulators in the process under study is formed. The methods of modern computational mathematics in combination with the mathematical support of computers include many applications software packages that allow solving various linear systems that arise in practice. The use of the MatLab package, which is a modern software tool for matrix calculations, ensures high accuracy of the results of calculations that were performed within the framework of this research. The theoretical basis of this research is the studies of scientists from all over the world who were engaged in the practical development of issues of improving the quality of public transport in countries with a high standard of living and human development. To improve the perception of the information provided and to obtain the most objective picture of the research, all the achievements of Russian authors taken in the order of citation and used as materials in this paper have been translated into English. Based on the collected theoretical data, a mathematical calculation of indicators that are of fundamental importance for obtaining qualitative results of this research was performed.

The whole complex of research works that form the basis of this study is divided into three main stages. At the first stage of this research, a theoretical analysis of studies in the field of prospects for the development of urban public transport was carried out in countries with a high level of social development and the human development index. The obtained theoretical material serves as a qualitative basis for subsequent practical research within the framework of the stated topic. At the second stage of research, a computer study of the main indicators of the economy was performed, based on which the results of mathematical modelling of the influence of the interaction of passenger traffic indicators on GDP were obtained and an assessment of the role of regulators in the process under study was formed. These indicators are of fundamental importance from the standpoint of obtaining high-quality results from research and forming final conclusions based on them, which reflect the entire complex of research works. In addition, at this stage of the research, an analytical comparison of the results obtained in the course of it with the results of other researchers on the issues put into the subject of this study was carried out to form the most balanced and objective results. At the final stage of the research, based on the results obtained, the final conclusions were formulated, which are a logical reflection of the study of passenger urban transport in countries with a high human development index. In general, the results of this research obtained using modern computer modelling methods, as well as the conclusions formulated on their basis, can serve as a qualitative scientific foundation for subsequent research aimed at studying a wide range of issues related to various aspects of the development of public transport in countries with a high human development index.

3 Results

The statistical reports obtained allowed obtaining the necessary statistical data on urban transport traffic (UTT), the dynamics of gross domestic product (GDP), and the mid-year population (MYP) from 2003 to 2018, distributed across nine countries in Europe, Asia, and America. Tables 1 and 2 were compiled based on these data, where Table 1 shows the ratio of UTT to MYP growth and Table 2 shows the ratio of GDP growth in the corresponding country. Table 1 shows the ratio of UTT to MYP growth, split by nine countries. The table shows that the ratio of urban transport passenger traffic to the mid-year population in eight countries, besides Japan, has increased over the past 16 years.

Research of urban passenger transport in countries with a high Human Development Index
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Table 1 The ratio of UTT growth to MYP, splitted by nine countries

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Russia	-0.01	-0.07	0.00	0.08	0.05	0.04	-0.02	0.01	-0.14	-0.08	0.01	0.03	-0.04	-0.08	-0.07	0.03
Belarus	-0.02	-0.14	0.20	-0.18	-0.25	-0.03	-0.05	-0.12	-0.10	0.03	0.04	0.14	0.00	-0.13	-0.09	-0.10
Hungary	0.01	0.05	-0.07	0.08	-0.06	-0.02	-0.09	-0.05	-0.02	-0.05	0.01	0.01	0.00	-0.01	0.00	0.01
Germany	-0.02	-0.06	0.07	-0.02	0.06	0.03	0.00	0.04	0.00	0.03	0.01	0.04	0.03	-0.01	0.02	0.04
Italy	-0.02	-0.02	0.00	-0.04	0.00	0.00	0.06	-0.01	-0.03	-0.02	-0.01	-0.05	0.10	0.02	0.04	0.00
Great Britain	0.00	0.02	-0.04	0.13	0.01	0.05	0.06	0.05	-0.01	0.04	0.04	0.03	0.01	0.04	0.02	0.02
Kazakhstan	0.29	-0.21	0.03	0.10	0.02	0.12	0.05	-0.01	-0.02	0.08	0.01	0.15	0.05	-0.09	-0.12	0.04
Japan	0.02	0.00	-0.01	-0.02	0.01	0.01	0.02	-0.01	-0.02	0.00	0.01	0.02	0.03	0.00	0.03	0.01
USA	-0.31	-0.03	0.04	-0.05	0.04	0.01	0.00	0.35	0.12	0.00	-0.01	0.01	0.06	0.00	-0.01	0.00

In Japan, in 2015 and 2017, there was an increase in the coefficient by 0.01. UTT in Japan increased by 12.5%, and MYP tended to increase between 2003 and 2010, with a downward trend between 2011 and 2018. In Kazakhstan, the coefficient under consideration was 0.29 in 2003 and 0.04 in 2018 [6]. In Russia, the coefficient increased due to a sharp increase in passenger traffic on urban transport by 75.5%, while the average population increased by only 20.81%.

Table 2 The GDP growth rate in the nine countries under consideration

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Russia	-0.05	0.00	0.02	0.00	-0.01	0.01	0.01	-0.03	-0.14	0.12	0.00	-0.01	-0.02	-0.01	-0.03	0.02
Belarus	-0.01	0.00	0.02	0.04	-0.02	0.01	-0.01	0.01	-0.10	0.07	-0.02	-0.04	-0.01	0.01	-0.06	0.01
Hungary	-0.04	0.01	0.00	0.02	-0.01	0.00	-0.04	0.01	-0.08	0.07	0.01	-0.03	0.04	0.02	-0.01	-0.01
Germany	0.01	-0.04	0.00	0.01	0.00	0.02	0.01	-0.03	-0.06	0.09	0.00	-0.03	0.00	0.01	0.00	0.00
Italy	0.00	-0.03	0.00	0.01	-0.01	0.01	0.00	-0.03	-0.05	0.07	-0.01	-0.03	0.01	0.02	0.01	0.00
Great Britain	-0.01	-0.01	0.01	0.01	-0.01	0.01	0.01	-0.05	-0.03	0.06	0.00	0.00	0.01	0.01	-0.01	0.00
Kazakhstan	0.00	-0.05	0.07	0.00	-0.07	0.03	0.05	0.00	-0.05	-0.03	0.06	-0.06	0.10	-0.07	0.00	0.01
Japan	-0.02	0.00	0.01	0.01	-0.01	0.00	0.00	-0.03	-0.05	0.10	-0.05	0.02	0.00	-0.01	0.00	0.00
USA	-0.03	0.01	0.01	0.01	-0.01	0.00	-0.01	-0.02	-0.03	0.05	-0.01	0.01	-0.01	0.01	0.00	-0.01

Table 2 shows the ratio of UTT to MYP growth, split by nine countries. In all the countries under consideration, there is no stability in the relationship between average GDP growth and average population growth. For example, in Kazakhstan, the ratio of GDP growth to MPG was 0.00 in 2003 and 0.01 in 2018, which indicates an increase in the value of GDP. In eight countries, the peak or highest coefficient (except Kazakhstan) occurred in 2012, which is explained by stable GDP growth. The value xn (n = 1,..., 16) entered in Table 1 determines the ratio of UTT to MYP in the 9 countries taken for the study, based on which Table 3 follows, representing the values of xn in ascending order, considering the minimum values and increments of units, splitted by 9 countries.

Table 3 A series for the variable x as a statistical series in non-decreasing order

	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}	x_{11}	x_{12}	x_{13}	x_{14}	x_{15}	x_{16}
Europe																
Russia	1.00	1.03	1.06	1.14	1.15	1.15	1.19	1.23	1.23	1.23	1.30	1.31	1.31	1.38	1.39	1.41
Belarus	1.00	1.07	1.11	1.13	1.15	1.16	1.19	1.27	1.27	1.31	1.36	1.39	1.74	1.77	2.00	2.04
Hungary	1.00	1.01	1.01	1.01	1.02	1.02	1.02	1.04	1.06	1.10	1.19	1.19	1.20	1.21	1.21	1.26
Germany	1.00	1.04	1.06	1.06	1.08	1.09	1.12	1.12	1.15	1.16	1.19	1.20	1.24	1.26	1.27	1.28
Italy	1.00	1.04	1.05	1.05	1.05	1.06	1.07	1.08	1.09	1.09	1.09	1.10	1.11	1.11	1.13	1.13
Great Britain	1.00	1.01	1.01	1.03	1.09	1.10	1.13	1.18	1.21	1.22	1.25	1.28	1.32	1.33	1.36	1.38
Asia																
Kazakhstan	1.00	1.01	1.03	1.10	1.12	1.20	1.21	1.23	1.25	1.26	1.29	1.30	1.32	1.32	1.41	1.46
Japan	1.00	1.01	1.04	1.05	1.05	1.06	1.07	1.08	1.08	1.09	1.13	1.15	1.16	1.23	1.24	1.34
America																
USA	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.03	1.04	1.04	1.04	1.04	1.04	1.05	1.05	1.05

It can be seen here that Belarus has the highest coefficient due to population growth, while the United States has the lowest. Let us assume that there is a one-to-one correspondence between the values of xn and yn, i.e., each value of the independent variable x corresponds to a given degree of accuracy to one value of the dependent variable y. In this case, the task arises to identify the form of the connection and determine the functional dependence that defines y as a function of f (x). Let f (x, a, b) be a function of one variable x with two parameters a and b, which approximates the dependence of the value of y on x. To determine the type of the function f (x, a, b), the results of arithmetic means are used in equation (1):

$$M_x(1) = \frac{1}{16}\sum_{i=1}^{16} x_i,\ M_y(1) = \frac{1}{16}\sum_{i=1}^{16} y_i, \quad (1)$$

geometric mean (equation (2)):

$$M_x(0) = \frac{1}{16}\sqrt[16]{\prod_{i=1}^{16} x_i},\ M_y(0) = \frac{1}{16}\sqrt[16]{\prod_{i=1}^{16} y_i}, \quad (2)$$

harmonic mean (equation (3)):

$$M_x(-1) = \frac{16}{\sum_{i=1}^{16}\frac{1}{x_i}},\ M_y(-1) = \frac{16}{\sum_{i=1}^{16}\frac{1}{y_i}}, \quad (3)$$

the quadratic mean (equation (4)):

$$M_x(2) = \sqrt{\frac{\sum_{i=1}^{16} x_i^2}{16}},\ M_y(2) = \sqrt{\frac{\sum_{i=1}^{16} y_i^2}{16}}, \quad (4)$$

cubic mean (equation (5)):

$$M_x(3) = \sqrt[3]{\frac{\sum_{i=1}^{16} x_i^3}{16}},\ M_y(3) = \sqrt[3]{\frac{\sum_{i=1}^{16} y_i^3}{16}}, \quad (5)$$

harmonic and quadratic mean (equation (6)):

$$M_x(-2) = \sqrt{\frac{16}{\sum_{i=1}^{16}\frac{1}{x_i^2}}},\ M_y(-2) = \sqrt{\frac{16}{\sum_{i=1}^{16}\frac{1}{y_i^2}}}. \quad (6)$$

The results of the mathematical calculations are presented in Tables 4 and Table 5.

Table 4 Mean values x_n

Country	$M_x(1)$	$M_x(0)$	$M_x(-1)$	$M_x(2)$	$M_x(3)$	$M_x(-2)$
Russia	13.64	11.50	7.29	14.83	15.67	3.79
Belarus	21.15	16.89	8.83	23.88	26.18	3.90
Hungary	9.06	7.66	5.53	10.04	10.82	3.52
Germany	9.03	8.00	5.92	9.59	9.99	3.63
Italy	6.10	4.94	3.82	7.26	8.35	2.9
Great Britain	8.29	7.26	5.51	9.06	9.82	3.56
Kazakhstan	25.26	20.56	9.73	27.61	29.49	3.94
Japan	3.90	3.50	3.02	4.21	4.46	2.54
USA	33.05	27.50	11.07	35.24	27.17	3.97

Table 5 Mean values y_n

Country	$M_y(1)$	$M_y(0)$	$M_y(-1)$	$M_y(2)$	$M_y(3)$	$M_y(-2)$
Russia	12.87	11.25	7.39	13.77	14.61	3.82
Belarus	9.63	8.47	6.12	10.30	10.82	3.66
Hungary	8.46	7.44	5.60	9.13	9.69	3.57
Germany	6.82	5.98	4.73	7.52	8.25	3.34
Italy	5.22	4.49	3.65	5.87	6.51	2.86
Great Britain	5.35	4.83	4.06	5.75	6.14	3.12
Kazakhstan	5.66	4.99	4.11	6.23	6.75	3.13
Japan	5.91	4.94	3.82	6.83	7.83	2.83
USA	3.68	3.23	2.77	4.12	4.59	2.34

Based on the calculated values of the independent variable x from the statistical data in Tables 4 and 5, find the corresponding values are found (equations (7), (8)):

$$M_x(1) \to y_1^*,\ M_x(0) \to y_0^*,\ M_x(-1) \to y_{-1}^*, \quad (7)$$

$$M_x(2) \to y_2^*,\ M_x(3) \to y_3^*,\ M_x(-2) \to y_{-2}^*, \quad (8)$$

As the research shows, passenger traffic strongly depends on the country's economy [7]. This can be seen from the graphical analysis as well as from the values of the correlation coefficients for certain time periods and the comparison of the two values: GDP and passenger traffic. Moreover, it is the country's economy (and its main indicator of GDP) that is the main factor affecting the total passenger traffic on transport. The extremely small value

of the correlation coefficient for the entire period under consideration is insignificant in this case.

4 Discussion

In the current economic situation around the world, the impact of public transport on the development of the economy is difficult to overestimate. The outstanding role played by transport in the issues of ordering and transforming the surrounding space to meet the needs of the population, as well as contributing to the transformation of the person into an individual on a planetary scale, allows defining public transport as an important component of social development, the qualitative and systematic functioning of which is a necessary condition for the development of society in general [8]. The evolution of the transport system of a single state in modern economic realities is determined by cyclical, avalanche-like, sharp changes in the parameters of the speed and scale of operations performed, which inevitably affect the systemic change in human views and ideas about the real possibilities of the existing transport system. It is necessary to consider the fact that a sufficient number of transport innovations have appeared in recent years, the existence of which confirms the development of prerequisites for revolutionary changes in the transport industry. The consistent transformation of the state's transport industry contributes to the creation of high-quality conditions for the implementation of large-scale economic changes that can improve the operation of the state's transport system as well as change the conditions of cargo and passenger transportation for the better [9].

In recent years, a considerable number of prerequisites have been created for improving the functioning of transport in many countries, and this trend is characteristic not only for states with a high human development index but also for developing countries. In assessing the real prospects for the development of the transport industry in general, it is necessary to consider the existing economic trends and problems of the development of the transport industry that need to be solved [10]. Timely solutions to urgent problems and tasks in the transport industry contribute to its full-fledged development, which has a positive impact on the economic development of a particular state in general. For the sustainable development of the transport system of any state, it is necessary to carefully identify the main innovative solutions that are important in the context of prospects for improving the efficiency of using conventional technical means designed to optimise the operation of the transport system [11]. Effective innovations intended for practical use in the development of transport systems in modern states can qualitatively change the economic situation in states for the better since they carry the prospects of improving the functioning of entire industries and individual systems [12]. Therewith, an important aspect is the ease of practical use of these innovative technological solutions and their availability for a wide range of users.

Nowadays, urban railway transport is in urgent need of increasing competitiveness compared to automobile transport, and the forecast of transport development prospects indicates the possibility of the appearance of vacuum transport systems and technological solutions based on the principles of magnetic levitation in cities in the future. Thus, these principles are the foundation for the functioning of the MagLev (Magnetic Levitation) magnetic suspension bearing system, which allows modern urban transport to move at higher speeds while maintaining proper safety standards, and the movement at the same time occurs at higher levels of transport highways above ground [13]. This considerably reduces travel time by eliminating the need for such vehicles to stay in traffic jams as well as by avoiding emergency collisions. When using transport of this kind, friction is practically reduced to a minimum value, which allows significantly increasing the speed of movement and reducing the likelihood of accidents, as well as energy costs for transportation. In addition, the use of such technology is completely harmless from an environmental standpoint. In addition to all the above, this technology allows for minimising air resistance so that the speed of vehicles operating through the use of these technologically innovative solutions can reach 3000 km/h [14].

In recent decades, projects of vehicles designed for use in the conditions of a modern city and combining the characteristics of an aeroplane and a car have been widely developed. Such transport innovations include the projects Terrafugia Transition (a flying car with folding wings), AeroMobil, Carplane, etc. The practical use of such technological solutions allows for qualitatively solving several important problems at once, such as eliminating traffic jams on highways, as well as considerably saving time for moving passengers and cargo. In general, the introduction of this innovation can bring the modern automotive industry to a qualitatively new level [15]. Modern creators of vehicles used in urban conditions in the field of public transport consider the needs of urban residents and the needs of people of various ages and belonging to various social groups. The purposeful implementation of the described trend implies the development of transport sociology as an independent discipline that describes the processes occurring in the public urban transport system from the standpoint of the norms and laws of modern science [16]. Therewith, it should be considered that improving environmental safety in combination with minimising energy costs during transportation using public transport are priority areas for the development of the modern transport industry in medium and large cities. To date, work has been completed in the United States to create a modern tractor powered by lithium-ion batteries and designed for the transportation of heavy loads. The maximum range for using such a vehicle without additional charging is 2000 km [17]. The use of a detailed device allows considerably expanding the possibilities of practical use of environmentally friendly

vehicles, provided that the energy necessary for the successful implementation of all current transport tasks is saved.

Public road transport has an extensive infrastructure and, in recent years, has often been put at the service of the ecological paradigm. For example, in France, a few years ago, as an experiment, traffic was opened along a kilometre-long stretch of road, on which solar cell parts were used as road surface elements. The mean value of the electric energy generated for this section of the road, according to approximate calculations, was 775 kWh per day. Therewith, the final peak output was at the level of 1500 kWh per day, which means almost doubled value. The generated electricity was used to meet the needs of a small village located in the vicinity of this road [18]. The problem of cargo transportation due to the use of technological resources in public transport is largely explained by the variety of environmental requirements that are currently imposed on transported goods, as well as the physical characteristics that are required to be maintained by vehicles intended for transportation of this kind. The heaviest and largest loads can be transported in batches of various volumes; urgent delivery of goods by public transport can be carried out by using small-sized vehicles. In any case, the challenges it faces and the opportunities for the development of public urban transport in each city and state determine the prospects for the development of modern public transport [19].

The prospects for the development of urban public transport are largely determined by modern socio-economic trends as well as technological innovations put forward. Considering the realities of the current economic situation in society, it is important not only to understand the trends of a macroeconomic and macrosocial nature but also to consider the individual requests of private entities and organisations for the functioning of modern transport systems. The urbanisation of modern society is the most important factor determining the requirements for the quality of public transport and the efficiency of its functioning. Economically developed states with a high standard of living and a high human development index have been concentrated around megacities for several decades now, which are also developing intensively in countries with a lower level of economic development [20]. The quality of public transport functioning in these and other states is determined by the requirements put forward by urban residents and individual organisations for the level of satisfaction of their needs with this transport. Modern public transport used in an urbanised society must meet the requirements of speed and reliability of transportation, be environmentally friendly and comfortable, and also produce as little noise as possible. Modern designers of vehicles intended for use in urban environments face a difficult task since it is not easy to create a device that can combine all of the above characteristics. The problems of urban transport require the development of comprehensive solutions that can meet the needs of a wide range of subjects and organisations, while preferences should be based on the specific features of the individual choice of public transport users [21].

Notably, there have been cases of companies offering such solutions, ranging from general concepts of public transport to specific samples of equipment intended for use in a modern city. Electric-powered vehicles that can compete with existing automobiles and rail-related vehicles have a special place among them. Electric vehicles are widely used in many countries for the transportation of passengers and cargo and have gained considerable popularity due to their quietness and environmental friendliness of use [22]. In addition, in a number of countries with a high human development index, unmanned electric-powered taxis and vehicles created using various innovative technologies have been successfully used for a long time. At the same time, public transport of the conventional type remains relevant and in demand since buses, trams, and trolleybuses are still widely popular among urban residents of different countries. Therewith, in a number of states and cities, conventional rail transport has already undergone considerable external transformations due to the introduction of innovative solutions that have largely changed both its appearance and the content of practical activities [23]. Modern urban rail transport still takes on large volumes of passenger and cargo transportation, while it is predicted that the trend towards a steady advance in the volume of rail transport compared to road transport will continue.

Since the population of countries with a high level of the human development index has a steady tendency to concentrate in and around large cities, in these states there is an increasing trend towards mobility of an unprecedented kind – both intercity, interstate, and intercontinental. The intensive pace of modern life in a large city, combined with the high value of the time of its residents, does not contribute to the development of trends for making long trips over long distances [24]. Citizens of modern cities tend to overcome any distance in small periods of time, so the consistent transition from long trips to short-distance travel is one of the main features of changes in the mobility of residents of modern cities, which has become possible with the development of the transport system over the past few centuries [25]. This is the reason for the focus of modern researchers' attention exclusively on certain types of transport, which implies the possibility of their consistent improvement. The quality of transportation plays a crucial role in this context; therefore, maintaining appropriate standards for the quality of public transport is currently the main task of the functioning of the entire public transport system in cities and countries with a high human development index.

5 Conclusions

The study of urban passenger transport features in countries with a high human development index led to the following conclusions: Passenger traffic is significantly

dependent on the state's economic development, as measured by GDP and the correlation coefficient within a specific time period. During the analysis of public transport development in relation to the economy of a particular state, it is important to compare the level of passenger traffic with the GDP indicator within a specific time period. It is worth noting that passenger transportation has some inertia. A sharp decline in GDP may result in a sudden drop in passenger traffic at a slower pace, while an increase in GDP may lead to a slower growth of passenger traffic. In other words, there may be a time delay between economic changes and changes in passenger traffic resulting from these changes. The correlation between passenger traffic and GDP has become particularly evident during certain 16-year periods. When communicating over longer time intervals, quantitative indicators lose their significance. Political and structural changes in society have a significant impact on the ratio of GDP and passenger traffic indicators. While the share of transport costs in GDP and household income may change, the strong dependence remains unchanged.

Passenger traffic depends on various political and economic factors, some of which cannot be quantified. In 2005, there was a significant drop in passenger traffic of 7.1%, despite a 6.4% growth in GDP. It is possible that the introduction of the law on monetization of benefits granted to the population played a role. It is worth noting that the most significant decrease in passenger traffic occurred on types of public transport such as buses, trolleybuses, trams, and metros. Additionally, it is important to note that the state continues to subsidize the majority of passenger transportation, including suburban transportation. Thus, this study can provide a qualitative basis for recommendations on prioritising the development of UTT based on the regression models obtained. This highlights the importance of the results for future research.

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Charting a sustainable course: how normative factors shape intentions for Autonomous Rapid Transit commuting
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Charting a sustainable course: how normative factors shape intentions for Autonomous Rapid Transit commuting

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***Keywords*:** Autonomous Rapid Transit, subjective norm, personal norm, green transport, sustainability.
Abstract: With the continuous advancement of technology, transportation methods have undergone significant transformation, giving rise to innovative solutions like Autonomous Rapid Transit (ART). ART systems are designed to utilize hydrogen energy, serving as an efficient and eco-friendly power source. This not only addresses issues related to traffic congestion but also presents a promising solution to environmental challenges. However, the success of implementing such technologies to mitigate these challenges relies heavily on the support and acceptance of potential users. This study aims to explore the intention of users to adopt ART as a mode of transportation in the context of Sibu, Sarawak, Malaysia. This study conducted a comprehensive survey involving 350 respondents and employed Partial Least Squares Structural Equation Modelling (PLS-SEM) to analyse the data. The findings of this study reveal that several critical factors significantly influence the behavioural intention to use ART for commuting. Specifically, subjective norms, perceived behavioural control, and individual attitudes have a significant impact on the intention to embrace ART as a sustainable mode of transportation. However, the study also finds that personal norms do not exhibit a significant relationship with behavioural intention. This insight underscores the pivotal role of societal influences compared to individually internalized values in shaping user decision-making with regard to the adoption of ART for commuting. It is imperative for policymakers to take into account the perspectives and considerations of users when formulating policies related to the introduction and promotion of new public transportation modes where private transportation has traditionally been prevalent.

1 Introduction

The rising economic growth worldwide has led to a tremendous increase in the need to travel and has changed how societies commute. Generally, greater travel needs lead to greater demand for transport. In developed Asian countries, the reliance on private transport coincides with the usage of public transport such as trains, trams, and public buses as well as non-motorized transport (NMT) like walking and cycling. This is contrary to many developing Asian countries, where the main mode of transport relies heavily on private vehicles such as cars and motorcycles. Statistically, there is a high level of vehicle ownership in developing countries (e.g., Malaysia: 542 motor vehicles per 1000 inhabitants; Brunei: 614 motor vehicles per 1000 inhabitants). Furthermore, there is a substantial growth in the level of car ownership, rising by approximately 64% from 2010 to 2021. High traffic flow indirectly contributes to environmental problems, including CO_2 emissions and air pollution [1]. According to [2], the transport sector is the third-highest contributor of CO_2 emissions (24.5%) in Malaysia, behind manufacturing and construction (35.1%) and electricity and heat production (29.3%). To solve these problems, urban road resources need to be redistributed, and a diverse, three-dimensional, and modern public transportation system needs to be established. The implementation of such measures is expected to mitigate the environmental impact of traffic congestion and promote sustainable transportation alternatives.

The Malaysian government developed its National Transport Policy to "Ensure efficient and sustainable use of resources and minimise environmental pollution" and to "Increase modal share for public transport". This has resulted in the Kuching Urban Transportation System (KUTS) being implemented in the Malaysian state of Sarawak with the aim of lessening traffic congestion on the roads while encouraging economic productivity. The Autonomous Rapid Transit (ART) system is one of the KUTS's efforts aimed at transforming public transportation in the state. This innovative public transportation system is powered by hydrogen energy and utilizes artificial intelligence (AI) technology. The introduction of ART is proposed to bring various benefits, such as energy efficiency by utilizing renewable energy source, reduced operational costs, and more, making it a promising addition to the transportation landscape. ART is set to be introduced in Kuching, Sarawak, connecting several key cities, including Serian and Kota Samarahan, by 2025 [3,4]. This development targets the provision of a public transportation option that supports the community's livelihood and fulfils its essential requirements. The benefits of using ART can be viewed from different angles. From an economic perspective, ART provides benefits such as reduced traffic congestion, increased productivity, and financial benefits to society. From an environmental perspective, ART is expected to contribute to a cleaner environment and the prevention of global warming. In terms of the advantages for society, taking public transportation, including ART, can improve health and meet the needs of an ageing population. Sarawak, the largest state in Malaysia, includes thriving urban centres such as Sibu, where rapid population growth and urban development have led to a sharp increase in road traffic and transport demand, resulting in significant traffic congestion, especially during peak hours. A positive disposition toward ART can signify reduced traffic congestion, lower carbon emissions, improved public health, and enhanced economic productivity, aligning with global Sustainable Development Goals (SDGs).

The benefits of ART on the environmental and urban transportation prompted this study to investigates users' intentions to commute by ART in Sibu, Sarawak. As the world faces urbanization on an unprecedented scale, understanding how individuals perceive and intend to use ART contributes to the transition to more sustainable, eco-friendly, and efficient public transportation systems. By assessing the readiness of a community like Sibu specifically to use ART, this research could inform policymakers and stakeholders on a path towards greener, healthier, and economically vibrant urban centres not only in Sibu but also in other regions. Furthermore, this study also contributes to the growing body of knowledge on transitioning urban mobility to a sustainable and green transport.

2 Literature review

2.1 Research elaboration

In 1980, the Theory of Reasoned Action (TRA) was introduced as the Theory of Planned Action (TPA) to predict an individual's intention to engage in a specific behaviour at a particular time and location. This theory not only offers insights into the factors that influence human actions but also provides a framework for understanding the likelihood of intentional behaviour being repeated. [5] further expanded upon this to formulate the Theory of Planned Behaviour (TPB) by introducing three key components for mapping individual preferences: subjective norms, attitude, and perceived behavioural control. These components provide a framework for analysing how subjective norms influence attitudes, which in turn impact behavioural intentions [1]. [5] asserted that behavioural intention is insufficient to fully explain a person's behaviour, adding the idea of perceived behavioural control to the current model to overcome this drawback. A more complete picture of the element influencing behaviour is provided by perceived behavioural control, which represents a person's confidence in their capacity to carry out a specific behaviour.

Personal norms are perceived as sentiments of a moral obligation to engage in a particular conduct and are connected to the self-concept [6,7]. To examine the influence of personal norms on people's decision to use public transportation, [8] employed the integrated theoretical framework, which focuses on theories regarding the social and psychological mechanisms that activate personal norms and moderate their influence on behaviour. The authors revealed that personal norms significantly predict the intention to use public transportation across different economic and socio-cultural backgrounds in German urban areas. Furthermore, the results were reported to link to expected emotions of guilt and perceived societal norms.

Using a sample of 465 responses gathered in Shanghai, [9] studied the potential role of norms and how an understanding of the challenges brought by auto traffic can affect decisions about the purchase of a car and choosing a form of transportation. The findings showed that descriptive norms have a negative relationship with car ownership. Moreover, personal and subjective social norms play a crucial role in fostering the intention to use public transportation and ultimately increase its actual usage. The results imply that the use of public transportation is influenced by an awareness of social problems that shapes personal norms and other people's expectations.

The impact of social and individual norms on people's intentions to use ecologically friendly transport alternatives was examined by [10] using a survey with 762 participants. The results showed that injunctive societal norms and behavioural intentions are not as strongly correlated as personal norms, which also reduces the

relationship between them. Injunctive social norms have a significant indirect impact on behavioural intentions through personal norms.

[11] investigated the relationship between social norms, happiness, and uses of public transport in six European cities. The results showed network coverage, trip speed, and service frequency are significantly linked with travel pleasure. Travel satisfaction is also influenced by perceptions of expenses, particularly reasonable ticket pricing, and norms, highlighting the significance of public transit in society and the environment. A study conducted by [12] provided evidence that moral norms have a positive association with the use of public transportation while pro-environmental norms have a limited link with travel behaviour.

[13] focused on the physical environment and fundamental service aspects of Kaohsiung's mass rapid transit system. The authors concluded that factors like engagement, satisfaction, and perceived value all play a role in how much service quality affects a person's conduct. With service attributes as the explanatory variable, psychological elements were added to the TPB model, with habit serving as the dependent variable. [14] examined the influence of psychological factors on mode choice behaviours in Khon Kaen's Bus Rapid Transit (BRT) system using the extended model. The findings revealed that the elements impacting mode choice behaviour and the customer's decision to employ a particular mode include service qualities, perceptions of attitudes, and social factors.

[15] was the first study to investigate behaviour intention focusing on autonomous vehicles in Hungary. According to the results, users with high and low personal information technology have considerably different perceptions of behavioural control when using autonomous vehicles. [16] assessed user behaviour using perceived attitude factors, subjective norms, and behavioural control on pro-behavioural intentions for urban rail transport. The results showed that in the Klang Valley region of Malaysia, perceptions of behavioural control, subjective norms, and environmental concerns are the most effective predictors of people's intentions to use public transport. [17] investigated Phnom Penh residents' urban rail transportation behaviour intentions in a similar setting. According to the study, the behavioural intentions of commuters in Phnom Penh are influenced by a variety of elements, including subjective norms, perceived behavioural control, moral obligations, knowledge of the consequences, attitude aspect variables, socioeconomic variables, and travel-related aspects.

[18] analysed the similarities and differences of attitudes between public and private vehicle users in Kuala Lumpur city centre. The findings indicated that both men and women believe that travelling with others, especially strangers, can affect the time of their trips because of potential delays caused by other passengers.

[19] investigated the relevance of behavioural determinants behind the desire to utilize the rail transportation system among road users in Kuala Lumpur, Malaysia. The researchers concluded that positive views on service quality and the benefits of using rail transportation are strongly associated with an intention to use it, with attitudes playing a partial mediating role. Furthermore, the study found that service quality has a greater impact on the intention to use for older age groups, while attitudes play a more significant role for high-income groups. Conversely, poor service quality results in negative attitudes, especially among high-income groups.

Despite the extensive body of research examining various determinants of travel behaviour and public transportation, a notable research gap exists concerning the specific context of ART in Malaysia. While previous studies have explored factors such as personal norms, subjective norms, perceived behavioural control, and attitudes in the context of traditional public transportation systems, the introduction of innovative modes particularly the ART, which incorporate cutting-edge technologies and sustainability elements, showed the importance of this study. Furthermore, Malaysia especially Sarawak, has been focussing on the implementation of ART and its potential to address pressing urban transportation and environmental challenges, it is essential to understand the unique factors influencing individuals' intentions to embrace this mode of transport. Research on this topic is particularly timely as it can provide insights into whether the public is receptive to the adoption of ART, thereby contributing to the success of Sarawak sustainable urban transportation initiatives. Additionally, examining the role of personal norms, attitudes, and other behavioural determinants in the specific context of ART in Malaysia will extend our understanding of how these factors may differ when applied to innovative and eco-conscious transit systems, which aligns with the global imperative of transitioning towards sustainable and green urban mobility solutions.

2.2 Hypotheses

The purpose of this study is to look at users' intentions to use ART in Sibu, Sarawak. Based on the literature review, the conceptual framework shown in Figure 1 is used. Subjective norms, personal norms, perceived behavioural control, and attitude are the independent variables and behavioural intention is the dependent variable.

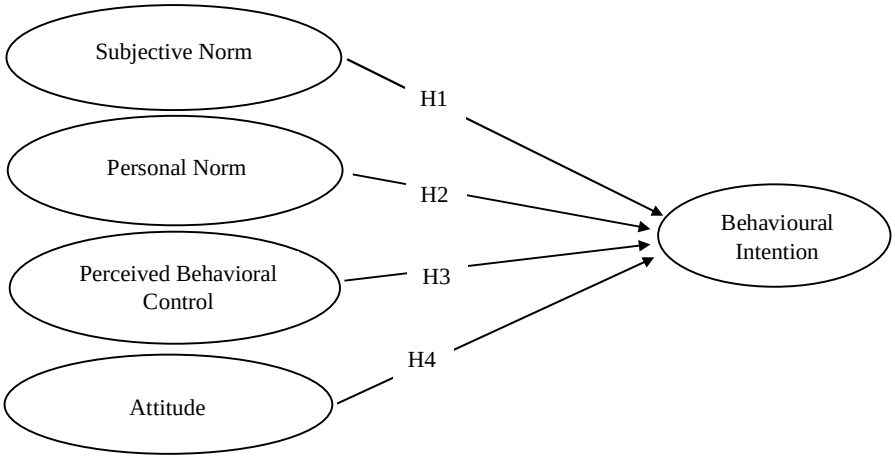

Figure 1 Conceptual framework

Accordingly, this study opted for the framework proposed by [5]. As depicted in Figure 1, the behavioural intention to use ART in Sarawak is possibly influenced by subjective norms, personal norms, perceived behavioural control and attitude. The factors are discussed as follow:

Subjective norms, which represent the social factors affecting individuals' decisions to engage in specific actions, are particularly imperative. Subjective norms are important social aspects that influence people's intention to engage in or refrain from specific acts. These norms, shaped by influential individuals and organizations, have demonstrated a significant impact on behavioural intent, despite some conflicting research findings several research show that they have a considerable and beneficial impact on behavioural intent. For instance, [14] encompass public expectations and perceptions of influences from significant others which may include family, friends, and others. This reflects an individual's perception of normative pressures and peer beliefs, influencing behavioural intention towards using public transit. [5] highlights the importance of subjective norms in influencing intentions to adopt and attitudes, emphasizing their significance in theoretical frameworks. Overall, subjective norms emerge as vital variables influencing the intention to adopt, attitude, and perceived control of behaviour in various behavioural models. Hence in the case of societal norms that gravitates towards private transport, users are less likely to use public transport. The hypothesis is given as:

Hypothesis 1: There is a negative relationship between subjective norms and behavioural intention.

Based on [7], "Self-expectations are experienced as feelings of moral obligation generated when perception of another's need activates the internalized structure of values and norms. The self-expectation process may be characterized as a normative explanation of helping based on internalized or "personal" norms." This is further elucidated by [8] in which they defined personal norms as the personal belief held by an individual on the moral correctness or incorrectness of a certain course of action. Their study also has proven that personal norm is significant in explaining public transport use. Thus, the hypothesis is postulated as follows:

Hypothesis 2: There is a positive relationship between personal norms and behavioural intention.

In the modern version of the reasoned action theory, perceived control of behaviour is defined by [20] as people's beliefs about their ability to perform a particular conduct or their level of control over it. On the other hand, [21] views perceived behavioural control as analogous to self-efficacy, which is the belief in one's own capacity to plan and carry out a specific task. Believing that one is capable of carrying out an action encourages people to attempt it and increases the possibility that they will follow through and complete their tasks. [22] have proven that perceived behavioural control significantly influences the intention to use public transportation. Consequently, the hypothesis is written as follows:

Hypothesis 3: There is a positive relationship between perceived behavioural control and behavioural intention.

[8] assert a connection between attitudes and the inclination to utilize public transport, suggesting that individuals' perspectives and opinions play a pivotal role in shaping their intention to engage with public transportation services. Similarly, [22] contribute to this perspective by reporting a relationship between attitudes and the intention to use public transportation. This collective body of research underscores the significance of individuals' attitudes in influencing their intention to opt for public transportation alternatives. The hypothesis derived from these findings can be posited as follows:

Hypothesis 4: There is a positive relationship between attitude and behavioural intention.

3 Research methodology

3.1 Respondents, procedure and measurements

A questionnaire was distributed to 350 respondents from April 2022 until May 2022. The questionnaires were created utilizing data collection tools and comprised closed questions with set answers. The survey questionnaires were used to study user intent to commute via ART in Sibu, Sarawak. A Likert scale was used to rank the respondents' level of agreement with all assertions, with 1 representing strongly disagree, 2 representing disagree, 3 representing neutral, 4 representing agree, and 5 representing strongly agree. The scales measurement from the questionnaire are derived from [22] and [23].

3.2 Partial least squares structural equation modelling (PLS-SEM)

The suggested model presented in Figure 1 was assessed using PLS-SEM, which was chosen because of its non-parametric character and prediction-based objectives. This was accomplished using SmartPLS 3.0, created by [24]. PLS-SEM is a two-step method that requires evaluating both the measurement and structural models. The fit indices evaluate the measurement model's indicator reliability, internal consistency, and convergent and discriminant validity. This material is delivered in an educational and unbiased tone, making it appropriate for a competent audience with a neutral formality in a wide domain intended to inform.

4 Results and discussions

4.1 Descriptive analysis

Of the 350 questions that were fully completed, 185 (52.86%) were completed by female respondents, while the remaining 165 (47.14%) were done by male respondents. In terms of age groups, 24 respondents (6.86%) were below 20 years old. Of the remainder, 267 (76.29%) were aged between 21 and 40 years old, 50 (14.28%) were aged between 41 and 60 years old, and 9 (2.57%) were above 60 years old. In terms of ethnicity, Malays had the highest number of respondents with 174, making up 49.71% of the total. Following them, there were 102 Melanau respondents (29.14%), 24 Iban respondents (8.29%), 20 Chinese respondents (5.71%), and 1 Indian respondent (0.29%). The respondents' educational status was taken into consideration and classified as primary school, secondary school, STPM or matriculation, diploma or equivalent, bachelor's degree, master's degree, and doctor of philosophy (PhD). No respondent had a PhD status. There were 2 respondents with a primary school education (0.58%), 97 respondents with a secondary school education (27.71%), 74 (21.14%) with an STPM or matriculation, 73 (20.86%) with a diploma or equivalent, 98 (28%) with a bachelor's degree and 6 (1.71%) with a master's degree. In terms of occupational status, the respondents were divided into the following categories: government sector with 89 respondents (25.43%), private sector with 21 respondents (6%), self-employed with 91 respondents (26%), retired with 8 respondents (2.29%), outside labour force with 5 respondents (1.43%), and others with 39 respondents (11.14%). Almost 80% of the respondents (n = 280) had a household income of less than RM4,850 while the remaining 70 respondents (20%) had an income of RM4,851 to RM10,970. The number of respondents with households comprising 1 to 3 people was 27.43% (n = 96), those with 4 to 6 people were 66% (n = 231), and those with 7 to 9 people were 6.57% (n = 23). Considering the presence of seniors in the family, 288 respondents (82.29%) did not live with a senior citizen, 34 respondents (9.71%) lived with one senior citizen, and 8% lived with two senior citizens. Meanwhile, 52 respondents (14.86%), 68 respondents (19.43%), 11 respondents (3.14%), 3 respondents (0.86%), and 4 (1.14%) respectively had one, two, three, four, or five children under the age of 12, while 212 (60.57%) had no children in their household. Table 1 describes the descriptive statistics of the respondents' profiles.

Table 1 Respondents' profiles

Background	Category	Frequency, N	Percentage (%)
Gender	Male	165	47.14%
	Female	185	52.86%
Age	< 20	24	6.86%
	21 – 40	267	76.29%
	41 – 60	50	14.28%
	> 61	9	2.57%
Ethnicity	Malay	174	49.71%
	Chinese	20	5.71%
	Indian	1	0.29%
	Melanau	102	29.14%
	Iban	24	6.86%
	Others	29	8.29%
Educational Status	Primary School	2	0.58%
	Secondary School	97	27.71%
	STPM or Matriculation	74	21.14%

	Diploma or equivalent	73	20.86%
	Bachelor's Degree	98	28%
	Master	6	1.71%
Occupational Status	Student	97	27.71%
	Government Sector	89	25.43%
	Private Sector	21	6.00%
	Self-Employed	91	26.00%
	Retired	8	2.29%
	Outside Labour Force	5	1.43%
	Others	39	11.14%
Household Income	< RM4,850	280	80.00%
	> RM4,850	70	20.00%
Number of people in a Household	1 – 3	96	27.43%
	4 – 6	231	66.00%
	>7	23	6.57%
Number of Senior Citizens	0	288	82.29%
	1	34	9.71%
	2	28	8.00%
Number of Children	0	212	60.57%
	1	52	14.86%
	2	68	19.43%
	3	11	3.14%
	4	3	0.86%
	5	4	1.14%

4.2 Assessment of the measurement model

The measuring model can be assessed via convergent validity and discriminant validity [25]. Convergent validity is the extent to which a set of indicators for a concept converge or illustrate a significant amount of shared variance, and it is assessed by examining the loading factor value, composite reliability (CR), and average variance extracted (AVE) [25,26]. Table 2 portrays the loading, CR and AVE values used to assess the convergent validity. The outer loadings indicate the strength of the relationship between each item and its respective construct. The CR scores evaluate the constructs' internal consistency reliability, whereas the AVE values quantify the amount of variance explained by the items regarding their respective constructs. The construct of attitude is made up of four elements (ATT1, ATT2, ATT3, ATT4), the construct of intention is made up of one item (BI), the construct of personal norms is made up of three items (PN1, PN2, PN3), and the construct of subjective norms is made up of two items (SN1, SN2). Table 2 shows that the outer loading for attitude is 0.697 to 0.829, for intention it is 1.000, for personal norms it is 0.475 to 0.970, for perceived behaviour it is 0.697 to 0.813, and for subjective norms it is 0.472 for SN1 and 0.917 for SN2.

Table 2 Convergent validity

Construct	Items	Loadings	CR	AVE
Attitude	ATT1	0.788	0.864	0.614
	ATT2	0.813		
	ATT3	0.697		
	ATT4	0.829		
Intention	BI	1.000		
Personal norms	PN1	0.970	0.740	0.509
	PN2	0.600		
	PN3	0.475		
Perceived behavioural control	PBC1	0.782	0.840	0.568
	PBC2	0.718		
	PBC3	0.697		
	PBC4	0.813		
Subjective norms	SN1	0.472	0.673	0.532
	SN2	0.917		

This measurement also provides an overview of the CR and AVE values for the four different constructs: Attitude, Personal Norms, Perceived Behavioural Control, and Subjective Norms. The construct of "Attitude" consists of four items (ATT1, ATT2, ATT3, ATT4); the CR for this construct is 0.864, indicating good internal consistency. The construct of "Personal Norms" constitutes PN1, PN2 and PN3. The construct also exhibits good internal consistency with a CR value of 0.740, suggesting that the items (PN1, PN2, PN3) within the Personal Norm construct are reliable and consistently measure the concept of personal norms. Similarly, the construct of "Perceived Behavioural Control" demonstrates good internal consistency with a CR value of 0.840 while "Subjective Norm" indicates an acceptable value of 0.673. The AVE value for attitude, personal norms, perceived behavioural control and subjective norm are 0.614, 0.509, 0.568 and 0.532 respectively which are greater than 0.5 that is adequate for convergent validity.

Table 3 presents the results for discriminant validity. The results in the table suggest that the discriminant validity is validated because none of the credibility ranges contain cohesion.

Table 3 Discriminant validity

	Attitude	Personal norms	Intention	Perceived behavioural control	Subjective norms
Attitude	0.783				
Personal norms	0.656	0.714			
Intention	0.254	0.138	1.000		
Perceived behavioural control	0.774	0.653	0.230	0.754	
Subjective norms	0.366	0.331	0.200	0.414	0.729

4.3 Assessment of the structural model

Figure 2 displays the results for the structural model. To test the relevance of the pathway coefficient, 5,000 bootstrapping runs were used in the PLS algorithm. This procedure was carried out to determine how consumer intention and ART are related. The PLS model's R^2-value of 0.178 shows that the independent variables and the dependent variable have a moderate relationship. The results support three of the hypotheses. Attitude, perceived behavioural control, and subjective norms have a strong association with the reported behavioural intention to commute using ART in Sibu, Sarawak. However, the results fail to support the hypothesis (H2), suggesting that personal norms do not influence the user intention to commute using ART. In summary, the PLS-SEM approach was successful in confirming hypotheses H1, H3, and H4.

Table 4 Hypothesis testing

	Hypothesis	Result
H_1	There is a negative relationship between subjective norms and behavioural intention.	Supported
H_2	There is a positive relationship between personal norms and behavioural intention.	Not Supported
H_3	There is a positive relationship between perceived behavioural control and behavioural intention.	Supported
H_4	There is a positive relationship between attitude and behavioural intention.	Supported

Figure 2 details the results for the relationship between subjective norms, perceived behavioural control, attitude, and personal norms towards behavioural intention. The variables' attitude and perceived behavioural control had a significant effect on behavioural intentions in this model. The effect of attitude on behavioural intentions was significantly positive ($\beta = 0.249$, $p < 0.10$), followed by perceived behavioural control ($\beta = 0.220$, $p < 0.10$). Then, subjective norms were recorded as significantly negative ($\beta = -0.367$, $p < 0.10$). However, the direct effect of personal norms on behavioural intention was insignificant ($\beta = -0.048$, $p > 0.10$).

Charting a sustainable course: how normative factors shape intentions for Autonomous Rapid Transit commuting

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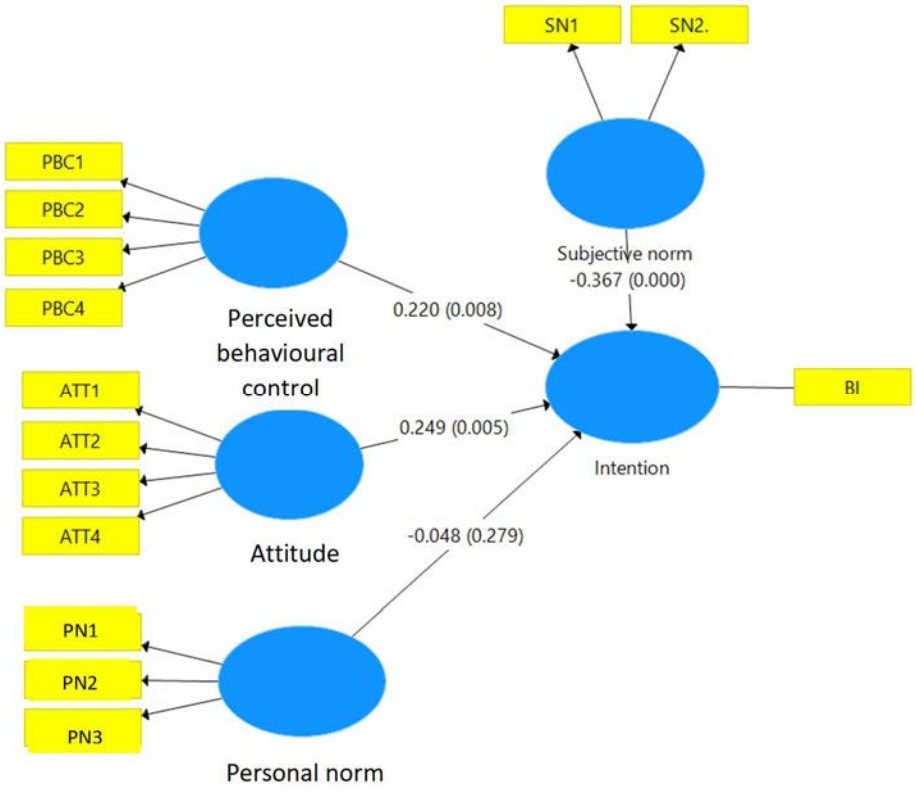

Figure 2 Structural equation model

4.4 Discussion

This study aimed to investigate the user intention to commute using ART in Sibu, Sarawak by analysing the role of subjective norms, perceived behavioural control, attitude, and personal norms. The TPB model served as the framework for this study, which used PLS-SEM to analyse data collected using a self-administered survey. Utilizing measurement evaluation and structural model assessment, the model was validated and evaluated.

The outcomes reported here are in agreement with the assumption that lies at the foundation of the hypotheses. This postulate asserts that there is a strong link between the variables of concern (attitude, perceived behavioural control, and subjective norms) and the desire to behave in a certain way. The TPB, which was mapped out by [5], is consistent with the obtained findings. According to this concept, attitude, subjective norms, and perceived behavioural control are all significant aspects that play a role in determining a person's intention towards their actions. The findings are consistent with [8-10] and [14].

The results of the study reveal that there is a positive association between attitude, perceived behavioural control, and behavioural intention concerning the mode of transportation that one chooses to use for the daily commute. It is hypothesised that a person's frame of mind has a significant role in determining the form of transportation that they choose, particularly for individuals who have a favourable frame of mind towards options that are better for the environment, such as ART, which is a transportation system that runs on hydrogen energy. The findings also indicate that people who have a greater perception of their own behavioural control are more likely to select public transport options that are convenient and dependable, such as ART. Furthermore, interventions aimed at promoting sustainable transport are associated with perceived behavioural control. Those who are aware of the positive impacts that using ART, which runs on renewable energy, has on the surrounding ecosystem are more likely to consider making their daily commute using this more sustainable alternative. The study also finds an inverse connection between an individual's subjective norms and their behavioural purpose. To put it another way, when people in Sibu, Sarawak are subjected to social pressure from those around them, their inclination to use ART for their everyday travel declines. This indicates the strong influence of the society that relies heavily on private based transport. On the other hand, personal norms, also known as individual-level standards, do not appear to have any influence on customers' intentions to commute via ART in Sibu, Sarawak. This insight underscores the pivotal role of societal influences compared to individually internalized values in shaping user decision-making with regards to the adoption of ART for commuting.

5 Conclusion

The introduction of ART in the Malaysian state of Sarawak is a significant step towards realizing the United Nations Sustainable Development Goal 11.2, targeting the provision of "access to safe, affordable, accessible and sustainable transport systems for all" by 2030. ART's role is also deeply rooted in the Malaysian National Transport Policy 2019-2030, which promotes the idea of delivering reliable, affordable, and sustainable transport for its populace. In alignment with Policy Thrust 4, "Advance towards a green transport ecosystem", this study resonates with strategy 4.5, which underscores the importance of "developing effective communication, education, and public awareness (CEPA) to create behavioural change towards sustainable transport". This study will assist policymakers in identifying factors that drive users' intentions or behavioural changes regarding ART. As ART is the most recent green transport initiative for Sarawak, it is crucial to understand which factors should be targeted and how an appropriate set of policies can be devised for the public. This is imperative considering that Malaysia, especially Sarawak, has a very high private transport dependency which may impose severe challenges to influencing the behavioural change regarding public transport.

Specifically, the findings of this study highlight the need to establish favourable attitudes and perceived behavioural control towards ecologically friendly options to promote sustainable mobility like using ART. This can be accomplished through awareness campaigns, education, and regulations that emphasise the benefits of environmentally friendly transportation for the environment and society as a whole. More people may be persuaded to select environmentally friendly commuting options by cultivating positive attitudes and improving their perceived behavioural control concerning the choice of sustainable transportation. This will contribute to a more sustainable future. Moreover, the finding of subjective norms shows a diminished impact on individuals' decisions regarding their choice of transportation depend upon the main preference of the society. Further research and exploration could shed light on the specific factors that shape individuals' transportation choices in Sibu, Sarawak and how various socio-economic, cultural, and environmental influences interact to impact sustainable commuting behaviours. Understanding these dynamics would be valuable for the development of effective strategies to promote and encourage the adoption of eco-friendly transportation options like ART in the region.

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The dynamics of port competition and efficiency in Vietnam amidst COVID-19: a decadal analysis

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Keywords: seaports, competition, efficiency, Data Envelopment Analysis, Vietnam.
Abstract: Vietnamese seaports play an important role as crossroads for import, export and transformation in delivery from maritime transport to rail, road and inland waterway transport. Over the last two decades, the seaport system has been reformed with the participation of private and foreign investors. Consequently, this issue enhances competition between seaports and brings changes to the seaports' operations. In this article, the relationship between seaport competition and efficiency is examined in the context of Vietnam, an emerging market economy. The longitudinal data from 2011 to 2022 is collected to quantify the competition degree of Vietnamese seaports and Data Envelopment Analysis is used to measure seaport efficiency. A number of measures are used to quantify the competition level of the seaport system over time, including concentration ratio, Gini index, and Hirschman-Herfindahl Index. Besides, market share at both national and regional levels and distance to the nearest competing seaport are criteria of port-level competition. The results advocate an increasing trend of seaport competition in Vietnam. Moreover, based on Tobit regression models, the competition among seaports relates positively to efficiency using both the 2021-2022 and 2015-2016 data sets. Under the COVID-19 pandemic, the impact of external factors on seaport efficiency is insignificant and inconsistent due to the disruption of logistics systems and disrupted links to the outside environment.

1 Introduction

The world has witnessed a rapid growth of international trade in goods over the last 15 years [1]. The commodity export in emerging countries has been almost doubled in spite of the global financial crisis since 2008 as a result of the globalisation of trade and increasing global production process. While more than 90% of the world's cargo is transported by ships [2], the development of seaport systems in emerging countries contributes significantly to the growth of export-import volume. For export-led and non-landlocked countries such as China and Vietnam, seaports are playing a role as transport hubs and contribute substantially in logistics supply chain operations [3].

In the context of the globalisation of production and logistics systems, substantial changes in cargo transportation forms and technological breakthroughs, in many countries the state-controlled port governance models were ended. Port reforms have been launched by governments in order to transform their port systems and adapt a new context and changing structures [4]. The contents of port reforms include a reduction of public roles, ownership structuring, and enhancement of the port quality and performance. As a result, the devolution of public sector from port operation and management has led to the increasing participation of the domestically private and foreign sectors. Depending on the roles taken by the private sector, there are five models of port governance [5], including public service ports, tool ports, landlord ports, corporatised ports and private service ports. While public service ports are totally operated and owned by the public sector, the private service ports are run by their corporation and individual investors. However, the dominate models include landlord ports and corporatised ports that support the major ownership of the states.

The participation of private investors leads to increasing competition between ports. Port competition can be unfolded at three levels [6,7]. At the first level, intra-competition occurs between terminal operators within a given port. The competition arena includes traffic routings, shippers and shipping lines. At the second level, terminal operators have to account for competition with terminal operators in other ports. The "inter-port competition" term can be displayed out at national and regional levels. At the highest level, inter-port competition can take place between terminal operators operating at different port

ranges. A port range is defined as a geographical area with several ports that possess largely overlapping hinterlands and thus serve mostly the same customers.

Competition can turn ports into focal points for collection of cargo and distribution of hinterlands. On the other hand, ports extend their boundaries and deal with problems of the whole logistics chain. Furthermore, port competition generates efficiency gain for the comparative and competitive advantages of their hinterlands. In particular, modern ports with supports from competitive and reliable transport services can raise econo-socio benefits of the port community and transport users [8].

The competition among ports brings about considerable impact [9]. Increasing competition can change the transport hubs and widen the geographical range of hinterland. Yap, Lam and Notteboom [8] find that competition among East Asia ports increased as the cargo hubs shifted to mainland China. Port competition also has impacts on port performance and government policies. The participation of foreign and local investors in port infrastructure development results in better port performance. In terms of strategic decisions, competition makes traditional business models unviable in landlord ports [10]. While competition has been mentioned widely in the literature, the impact of competition on port efficiency, especially detailed and in-depth empirical research, are scarce. Many studies point out the importance of port efficiency to port competitiveness in particular, and to regional and national competitiveness in general. Thus, investigating the impact of competition on port efficiency is greatly significant in the increasing port competition context.

On the one hand, the impact of competition on port efficiency is diverse due to various factors, including market changes, hinterland influences, port strategies and management practices, etc. [11]. On the other hand, this relationship is different in the perspectives of specific countries or regions, resulting in inconsistent findings. Consequently, this limitation can be addressed by in-depth empirical studies on the impact of competition on the essence of port efficiency.

In Vietnam, seaports are playing a very important role as the hub of national transportation system when 90% of the country ‘s export-import cargoes is transported through its seaports. Moreover, seaport tariff contributes to 20% of national budget revenues. In the last two decades, the seaport system has undergone a substantial change in the ownership structures through a corporatisation process [12]. A number of state-owned enterprises were established to operate Vietnamese seaports. Overseas or domestic private investors can take part in port operations via venturing, acquiring or being minor shareholders of corporate seaports. As a result, ports can be owned and operated by public, private, foreign investors, and local/central government. Profit-based objectives of port corporations have fostered competition. In the aftermath of the WTO entry from 2007, a significant increase of FDI capital results in a surge of international trade mainly through the country’s seaport system [13]. Besides, provision of port services is a profitable business and attracts many potential investors. Port operators have invested heavily in berth construction, warehouse and handling equipment. These investments have raised considerable competitive advantages for the ports. In addition, issuance of Maritime Law in 2015, Law of Sea in 2012 and Master Plan for Seaport Development in 2021 have paved the way for developing Vietnamese seaports. Vietnam's seaport system currently has 286 ports, distributed in 5 groups of seaports, with a total length of more than 96 km, and infrastructure to meet the throughput of more than 733 million MT in 2022 [14]. Established gateway ports combining with international transshipment in the North and the South has received container ships up to 132,000 DWT at Lach Huyen Wharf (Hai Phong), up to 214,000 DWT at Cai Mep Wharf (Ba Ria - Vung Tau).

The investments in seaport infrastructures and reform of ownership and governance have fostered competition. However, Vietnamese seaports have competed among others mainly through port service prices. Three rationales are behind this fact. First, the seaport system is moderately fragmented, including many small ports. For example, the port cluster in Haiphong city, the biggest cluster in the North of Vietnam, includes 60 ports operating along 10 km of Cam riverbank and they are operated by many port operators (Vinalines, New Port, Gemadept, Haiphong port corporation, Viconship…). With many port operators and short distance between ports have led to substantial competition through decreasing port service price. The same curriculum occurs in the South and the Central of Vietnam. Second, no significant difference of services providing to customers also intensifies the competition between ports. Last, port industry has hard barriers to exit. Due to the specification of seaports, their fixed assets and infrastructures cannot be moved to other places or reused by other industries. In the context of Vietnam, some may consider whether increasing competition can result in better performance of the seaport system.

This paper aims to investigate the seaport competition – efficiency relation in Vietnam. To measure seaport competition, this study uses several indexes including Hirschman-Herfindahl Index, Gini index and concentration ratio, with longitudinal data covering the 2011-2022 period. Port efficiency is estimated by Data Envelopment Analysis with the data of 44 seaports over the 2021-2022 period. The Tobit models are used to regress port competition on efficiency. Contributions of our research are twofold. First, this study is unique that investigates the impact of competition on seaports’ performance in an open, small and emerging market economy. Second, this is the first time that seaport efficiency is measured and analysed between pre- and during-COVID-19 periods.

The rest of this study is organised as follows. Section 2 presents the methods utilised to measure port competition

and port efficiency. Section 3 provides details on inputs, outputs and environmental variables. Empirical analysis is included in Section 4 while concluding remarks are provided in Section 5.

2 Methodology

In this section, a number of competition measures and measures to port efficiency are presented.

2.1 Measures of port competition

(1) Market share

The market share of port i at time t (MS_{it}) (1) can be described as the ratio between the throughput volume of port i at time t (V_{it}) and the total throughput volume of the port system at time t ($\sum_{i=1}^{n} V_{it}$).

$$MS_{it} = \frac{V_{it}}{\sum_{i=1}^{n} V_{it}} \quad (1)$$

Due to the Vietnamese long coast from the North to the South, the country can be divided into three regions, including the southern, central and northern region [15]. Hence, market share at both national and regional level are included to present the competition degree. A port owned a higher proportion of market share is expected to have better contestability.

The market share of port i at time t of the region r can be identified as below (MS_{itr}) (2):

$$MS_{itr} = \frac{V_{itr}}{\sum_{i=1}^{m} V_{itr}} \quad (2)$$

where V_{itr} is the throughput volume of port i at time t of the region r and the total throughput of the region r at the time t is $\sum_{i=1}^{m} V_{itr}$.

(2) Concentration ratio (CR_K)

Concentration ratios reflect the level of competition within an industry and higher ratio value means more market entry barriers for new investors [16]. The CR_{Kt} (3) is presented for the market share of the K biggest ports in terms of throughput volume at the time t.

$$CR_{Kt} = \frac{\sum_{j=1}^{K} V_{jt}}{\sum_{i=1}^{n} V_{it}} \quad (3)$$

In this paper, K takes two values, including 4 and 8. The concentration ratio varies between 0 and 1.

(3) Gini index

Gini index can be defined as be low (4):

$$G_t = \frac{n-1}{n} - \frac{2\sum_{i=1}^{n}(n+1-i).X_{it}}{n.\sum_{i=1}^{n} X_{it}} \quad (4)$$

where X_{it} is the cumulative market share of the throughput volume of the port i at the time t in the condition that the throughput volume is sorted in increasing order. The Gini index's value ranges from 0 (perfect equality) to 1 (perfect inequality), reaching 1 when the market is dominated by only one port and is 'fully concentrated', and reaching 0 when there is no inequality between the throughput volumes at the respective ports. The higher value of Gini index demonstrates a lower level of equality among ports.

(4) Hirschman-Herfindahl Index (HHI)

The HHI (5) is calculated by summing the squared market share of all the ports in the port system.

$$HHI_t = \sum_{i=1}^{n} \left(\frac{V_{it}}{\sum_{i=1}^{n} V_{it}}\right)^2 \quad (5)$$

The HHI is among the best tools for determining the degree of concentration. The HHI ranges from 1/n to 1. In general, a HHI between 0.15 and 0.25 indicates moderate concentration, while above 0.25 indicates high concentration [17]. If the port system includes only one port, the HHI attains maximum value of 1. On the other hand, if the throughput of each of the ports in a given system is the same, then the HHI equals its minimum value of 1/n.

Above concentration-based measures do not take into account cross ownership where a firm owns shares in a competitor or common ownership where two rivals have shares in common. This type of ownership may reduce the incentives to compete for what seems independent firms.

2.2 Estimating port efficiency

Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA) are the two dominating methods in measuring port efficiency [18]. DEA is a non-parametric linear programming approach. One of DEA's advantages is that it does not require any assumptions on the firm's production technology. However, DEA methods have difficulties in testing hypotheses, a problem which can be solved when using a stochastic approach. In SFA methods, the form of a cost or production function is assumed in an ad hoc manner and estimated with a two-part composite error term.

In this study, two-stage DEA is applied to measure and analyse the possible factors influencing seaport efficiency. At the first stage, DEA is used to measure port efficiency. When the inefficiency scores are estimated, they will be regressed again a set of environmental variables at the second stage. Under the assumption of free disposability of inputs and outputs, and variable returns to scale, the DEA estimate of the production set can be defined as (6):

$$\widehat{\wp} = \left\{ \begin{matrix} (x,y) \in \mathbb{R}_+^p \times \mathbb{R}_+^q : \sum_{k=1}^{n} z_k y_k^i \geq y^i, i = \\ 1, \dots, q;\ \sum_{k=1}^{n} z_k x_k^j \leq x^j, j = \\ 1, \dots, p;\ \sum_{k=1}^{n} z_k = 1, z_k \geq 0 \end{matrix} \right\}, \quad (6)$$

where $x \in \mathbb{R}_+^p$ denotes a $(1\times p)$ vector of inputs and $y \in \mathbb{R}_+^q$ denotes a $(1\times q)$ vector of outputs. y_k^i is the quantity of

output *i* of unit *k*. x_k^i is the quantity of input *i* of unit *k*. z_k is the respective weight of unit *k*. *n* is the total number of units.

Due to the fact that some inputs of seaports such as berth length or terminal area are quasi-fixed and cannot adjust for a better performance, assumption of output-orientation is applied in our DEA models [19]. The DEA output-oriented estimator of δ for variable returns to scale production can be written as (7):

$$\hat{\delta} = \delta(x, y \in \widehat{\wp}) = max\left\{\begin{matrix}\delta > 0: \sum_{k=1}^{n} z_k y_k^i \geq \delta y^i, i = \\ 1, \dots, q; \sum_{k=1}^{n} z_k x_k^j \leq x^j, j = \\ 1, \dots, p; \sum_{k=1}^{n} z_k = 1, z_k \geq 0\end{matrix}\right\}. \quad (7)$$

To investigate the impact of environmental variables on port efficiency, the Tobit regression model is utilised in this research at the second stage. Tobit is a widely used method to model the DEA (in)efficiency scores against exogenous factors, which is suitable when the dependent variables are either censored or corner solution outcomes [20]. In this paper, the dependent variable is output-oriented inefficiency scores, which is larger or equal to one at least. The higher score value indicates a lower level of efficiency and a seaport is considered to be efficient if its score is one.

3 Data

Input and output variables

The production process of ports demands capital, land and labour resources as inputs to produce outputs [21]. Capital is an important input of ports but also the most difficult to measure. The common monetary proxies of capital can be book value of assets or depreciation [22]. On the other hand, capital can be proxied by physical assets such as the total length of berths, number of berths, number of cranes or total number of pieces of equipment [23]. Land resource used by seaports is quantified by the size of terminal area or the size of warehouse area [24]. Labour resource is difficult to identify as port authority labour is often outsourced. Due to the fact that port industry is highly capital-intensive, port operators tend to substitute away from labour towards more mechanized or automated technology. The labour input is proxied by the number of port authority employees, or expenditure on salaries. In this research and based on the availability of data, four inputs is chosen including total berth length (BL), terminal area (TA), warehouse area (WA) and total pieces of equipment (Eq).

Regarding output variables, the most important output measure is the amount of cargo handled at the seaports [25]. Due to the multi-product nature of port production, a number of output variables can be utilised, including the volume of containers (in TEUs or MT), bulk cargo (in MT), general and rolling freight (in MT) [26]. Some studies use monetary measures including total revenue or net income as alternatives of port output [27]. Qualitative measure of output is also considered and can be obtained via user satisfactory survey [28].

While the above mentioned outputs of seaports are desirable, authorities and local communities also consider CO_2 emission from port operations. These negative externalities should be accounted as undesirable or bad outputs [29]. In the case of the Vietnamese port sector, most of seaports are multi-purpose ports, and only data for total cargo throughput is provided for all the ports. Thus, annual total throughput is chosen as the unique output of our DEA models.

Environmental variables

This research aims to examine the impact of inter-port competition on Vietnamese seaport efficiency. There are several measures for port competition. The distance to the nearest seaport is used for the proxy of inter-port competition [30]. Oliveira and Cariou [31] use HHI concentration index and market share to quantify the competition degree of container terminals. Adler et al. [28] develop a competition measure based on distance to and size of competing ports. In this study, market share is utilised as proxy of Vietnamese seaport competition. This proxy is measured at national and regional level. Furthermore, the distance to the nearest competing seaport is another proxy for port competition in Vietnam. It is assumed that the competitive pressure to a seaport is harder if the distance to the nearest seaport is shorter. Consequently, the seaport must operate efficiently to increase its competitiveness compared with its neighbouring seaports.

Over the last two decades, many Vietnamese seaports have transformed their ownership structures from being totally owned by SOEs or government to corporations, in which domestically private and foreign investors can take part. To assess the impact of this process, the OWN dummy is included in the regression models, taking the value of one if the seaport is a corporation and zero if they are wholly SOEs or managed by governments.

Due to the different economic-social conditions among three Vietnamese regions, the location of seaport is an important factor influencing port efficiency and competition. The geographical character of seaports is proxied by two dummies. The dummy variables GS and GC are used for seaports located in the South and Central respectively, whereas seaports in the North are treated as the base group.

The increasing trend of exporting manufactured goods stimulates containerisation of Vietnamese logistics system. As a result, the impact of containerisation on Vietnamese seaport operation should be assessed. The environmental variable CNS is a dummy variable representing the operational setting of the port, i.e. whether it handles container cargo and ships or not. CNS is equal to one if seaports serve container ships and zero for others.

The data of 44 Vietnamese seaports in the 2021-2022 period has collected from the website of Vietnam Seaports

Association (www.vpa.org.vn). Table 1 provides descriptive statistics on inputs, output and environmental variables. Table 2 describes the correlation between environmental variables utilised in regression models.

Table 1 Inputs, output and environmental variables

Variables	Description	Unit	Min	Max	Mean	St. dev.
Output						
Throughput (O)	Annual total throughput	MT	21,931	30,424,620	5,268,133	6,659,365
Inputs						
Berth length (BL)	Total berth length in meter	Meter	104	3,213	598	532
Terminal area (TA)	Total terminal area in square meter	m2	1,200	796,979	143,872	151,030
Warehouse area (WA)	Total warehouse area in square meter	m2	900	50,000	12,826	12,927
Equipment (Eq)	Total number of cranes, tractors, trucks	Number	5	312	48	53
Environmental variables						
South location (GS)	Dummy variable for seaports locating in the southern area of Vietnam	1 or 0	0	1	0.3409	0.4740
Central location (GC)	Dummy variable for seaports locating in the central area of Vietnam	1 or 0	0	1	0.3750	0.4841
Container serving (CNS)	Dummy variable for seaports serving container lines	1 or 0	0	1	0.5682	0.4953
Ownership (OWN)	Dummy variable for seaports operating under the corporation model	1 or 0	0	1	0.7386	0.4394
National market share (NMS)	The proportion of the national total throughput is penetrated by a seaport.	Percentage	0.0001	0.0854	0.0144	0.0185
Regional market share (RMS)	The proportion of the regional total throughput is penetrated by a seaport. There are three regions, including the northern, central and southern region.	Percentage	0.0002	0.3149	0.0519	0.0687
Distance to the nearest seaport (D)	Measured in km from a seaport to its nearest rival.	km	1	130	32	40

Table 2 Correlation matrix of the environmental variables

	GC	GS	OWN	CNS	NMS	RMS	LogD
GC	1						
GS	-0.5571	1					
OWN	-0.5543	0.4278	1				
CNS	-0.1777	0.143	0.2124	1			
NMS	-0.3032	0.1507	0.2068	0.4602	1		
RMS	0.0435	-0.2293	-0.0033	0.4423	0.7881	1	
LogD	0.5406	-0.4354	-0.5392	-0.2376	-0.3767	-0.0956	1

Notes: GS: Southern area location; GC: Central area location; CNS: serving container ships; OWN: Ownership; NMS: market share at national level; RMS: market share at regional level; LogD: logarithm 10 form of the distance to the nearest port.

4 Empirical analysis

4.1 A longitudinal analysis of Vietnamese seaport competition

The 2011-2022 period has witnessed a significant increase of total cargo throughput in the Vietnam's seaport system. In 2011, the total throughput is about 157 million MT and this figure has been tripled in a decade when reaching 397.5 million MT in 2020. However, due to the impact of COVID-19 pandemic and disruption of global logistics system, the cargo throughput has slightly decreased to 356 million MT in 2021 and 369 million MT in 2022 (see Figure 1).

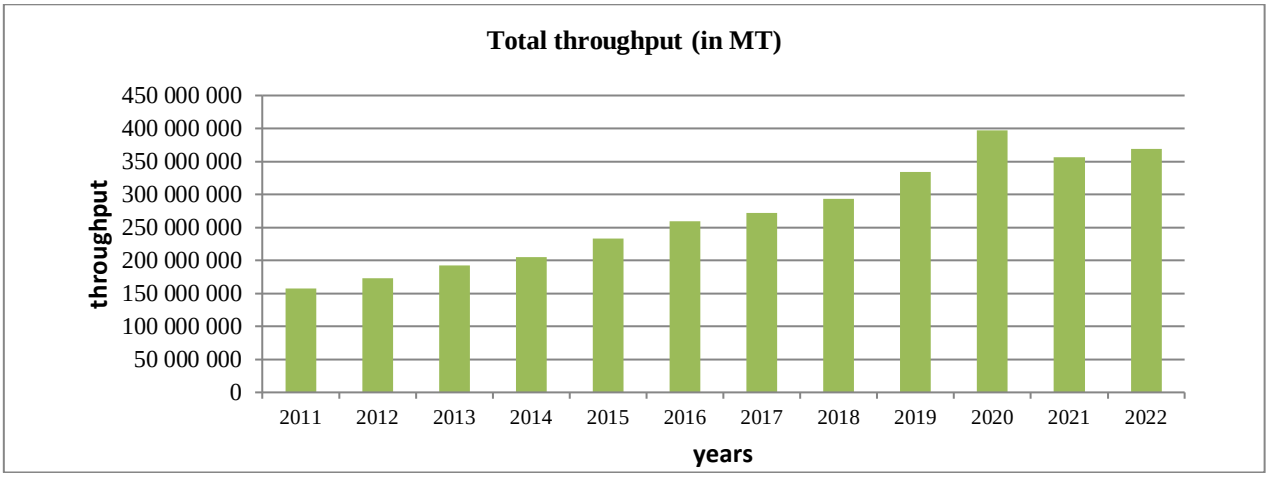

Figure 1 Annual total throughput of Vietnamese seaports from 2011 to 2022
Source: Vietnam Seaports Association

To quantity the degree of competition of Vietnamese seaport system, three measures of competition are utilised in this study, including Hirschman-Herfindahl Index (HHI), Gini index and two types of concentration ratio (CR_4 and CR_8). According to Notteboom, Ducruet and De Langen [17], if the HHI varies between 0.15 and 0.25 indicating moderate concentration, and the indexes with above 0.25 values indicates high concentration. The HHI is under 0.1 in the context of Vietnam, thus this result suggests a competitive and dispersed seaport market. The linear curve of HHI does not show a decreasing or increasing trend (see Figure 2). In contrast, the Gini index shows an increasing trend of competition in Vietnamese seaport system and this index has grown from around 0.6 in 2011 to about 0.7 in 2022 (see Table 3). Both two concentration ratios (CR_4 and CR_8) have decreased during the 2011-2022 period, indicating the lower level of seaport concentration or a higher level of competition. The CR_4 fluctuates between 0.43 and 0.47 during the 2011-2022 period and implies a low concentration level, following the standards suggested by Notteboom [32]. The mentioned standards reveal a competitive seaport market if the CR_4 is under 0.4, and a highly concentrated market if this measure is above 0.7. In general, an increasing trend of Vietnamese seaport competition can be observed via the empirical results of this research. This finding is in line with Pham et al. [33] when they point out a deconcentration trend of container terminals in Northern Vietnam.

Table 3 Measures of Vietnamese seaport competition from 2011 to 2022

Year	Herfindahl - Hirschman Index	Gini coefficient	CR4	CR8
2011	0.0697	0.6064	0.4655	0.6035
2012	0.0787	0.5973	0.4743	0.6131
2013	0.0865	0.5976	0.4696	0.6087
2014	0.0775	0.6082	0.4286	0.5656
2015	0.0764	0.6238	0.4290	0.5665
2016	0.0828	0.6497	0.4381	0.5856
2017	0.0875	0.6535	0.4474	0.5895
2018	0.0846	0.6396	0.4468	0.5701
2019	0.0814	0.6386	0.4443	0.5629
2020	0.0773	0.6589	0.4683	0.5880
2021	0.0781	0.6549	0.4311	0.5545
2022	0.0757	0.6856	0.4299	0.5546

(Source: Authors' calculations)

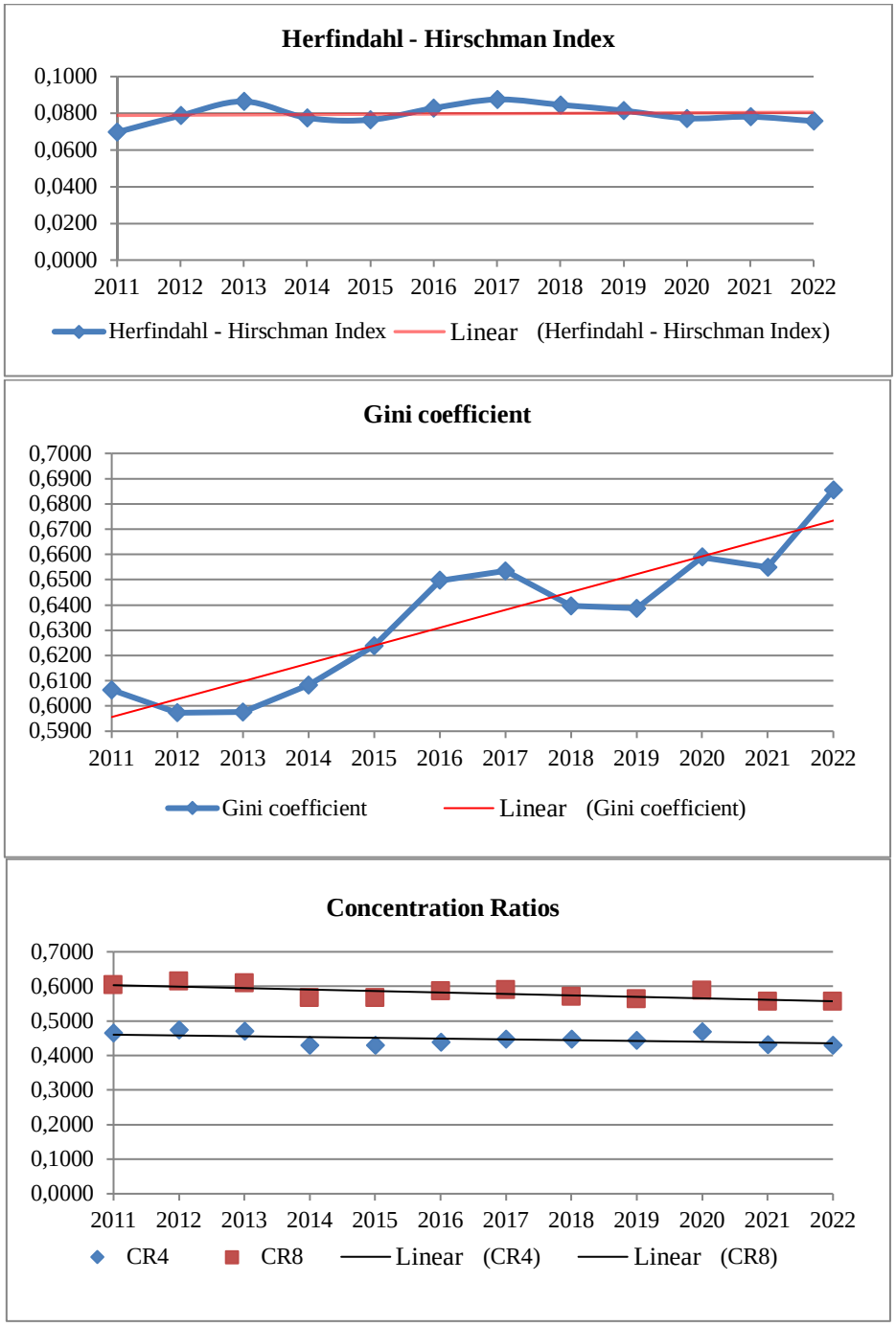

Figure 2 Measures of seaport competition in Vietnam

4.2 Estimating seaport efficiency

Estimates of Vietnamese seaport efficiency is presented in Table 4. The range of inefficiency scores is between 2.5 and 3.9, indicating that port operators can extend their output from 2.5 to 3.9 times to achieve the optimal level. Southern seaports having the highest inefficiency scores are the least efficient when compared to their competitors in the central and the north of Vietnam.

Table 4 Estimates of Vietnamese seaport efficiency using output-oriented DEA

Year	Northern seaports	Central seaports	Southern seaports	All seaports
2021	2.5674	3.5421	3.9377	3.4081
2022	3.1521	3.2888	3.5989	3.3527

4.3 The impact of competition on seaport efficiency in Vietnam

Table 5 demonstrates regression results on the impact of environmental variables on seaport efficiency with the data of Vietnamese seaports over the years 2021-2022. All models show that a higher level of market penetration leads to a lower inefficiency score or a better efficiency performance of Vietnamese seaports using both national and regional market share as proxies of competition. Accordingly, seaports with higher degree of competition can operate more efficiently when generating more output with a given level of inputs in a comparison with other rivals. Oliveira and Cariou [31] also found a positive relation between market share and port efficiency when using the data of international container terminals.

The results also point that the location of seaports is not important in determining seaport efficiency. The coefficients of GC and GS variable are insignificant in all different models. Moreover, the coefficient of OWN variable is insignificant, indicating that owning to a corporate or a government body does not make changes to the performance of seaports. The outcomes relating to CNS variable reveals an inconsistent impact of container service provision on seaport efficiency. While models 1 and 4 show a negative and significant impact of CNS, models 5 and 8 provide insignificant results.

It is worth to note that the results presented in Table 5 is based on the data of the 2021-2022 period. Consequently, the COVID-19 pandemic can distort the results when the supply chain is disrupted and the operation of seaports is influenced by the pandemic. To eliminate the possible impact of COVID-19 on the seaport competition – efficiency relationship, the data of Vietnamese seaports between 2015 and 2016 (the data of Vietnamese seaports between 2015 – 2016 is chosen due to its availability) was used in the paper (see Subsection 4.4).

Table 5 Tobit regression results on the impact of competition on Vietnamese seaport efficiency using the 2021-2022 data

	Competition at national level				Competition at regional level			
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Intercept	3.491842***	4.345569***	3.527112***	3.770339***	3.095387***	3.897906***	3.723422***	3.647804***
	(.9671533)	(.6781914)	(.6266528)	(.4817341)	(1.019437)	(.7066052)	(.688728)	(.5039701)
GC	-.3492276	-.5410136			.5403358	.2299541		
	(.8514633)	(.7990061)			(.8798798)	(.8152777)		
GS	.4746387	.6869272			-.2328084	.0903776		
	(.7916445)	(.7907802)			(.8756124)	(.8571717)		
OWN	.550408		1.123657		.5892393		.3957192	
	(.8451623)		(.7211491)		(.8980055)		(.7441298)	
CNS	1.175607*			1.319926*	.9637398			.9101956
	(.7028189)			(.7071907)	(.7625448)			(.7279153)
NMS	-104.5891***	-88.80059***	-87.74217***	-99.726***				
	(20.53404)	(18.59801)	(18.21191)	(20.23346)				
RMS					-20.9711***	-17.3714***	-17.38379***	-20.26743***
					(5.522699)	(4.894584)	4.730448	(5.218391)
No of Ports	44	44	44	44	44	44	44	44
Observations	88	88	88	88	88	88	88	88
LR χ^2	25.27	21.77	21.56	22.60	14.73	12.50	21.56	13.97
Pro>χ^2	0.0001	0.0001	0.0000	0.0000	0.0116	0.0059	0.0000	0.0009
Log likelihood	-195.25571	-197.00521	-197.11119	-196.58977	-200.52399	-201.64076	-197.11119	-200.90546
Pseudo R^2	0.0608	0.0524	0.0518	0.0544	0.0354	0.0301	0.0518	0.0336

Notes: GS: Southern area location; GC: Central area location; CNS: serving container ships; OWN: Ownership; NMS: market share at national level; RMS: market share at regional level. The coefficients with * and *** are significant at 10 and 1 percent, respectively. Standard errors are included in parentheses.

Table 6 provides Tobit regression models on the relation between the distance to the nearest seaport and efficiency. Using the data in the pre-COVID-19 period (2015-2016) and COVID-19 period (2021-2022), the findings show that the distance to the nearest seaport relates negatively to the seaport efficiency. Thus, the seaport with a shorter distance to the nearest port and facing more competitive forces possesses a higher level of efficiency. This finding is also in line with Yuen, Zhang and Cheung [30] when they find that the inter-port competition as proxied by the distance to the nearest port has a positive impact on the efficiency of Chinese container terminals. The variables indicating seaport location (GS, GC) and ownership (OWN) are insignificant. The CNS variable is significant in models 1 and 4, demonstrating a positive relation between container service provision and seaport efficiency.

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Table 6 Tobit regression results on the impact of competition on Vietnamese seaport efficiency with the distance to the nearest seaport variable

	2015-2016				2021-2022 (under COVID-19 impact)			
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Intercept	1.730233*	.6373331	1.412006*	1.831922**	.3284799	1.113903	.7718357	2.421013***
	(.8884652)	(.7073094)	(.8425226)	(.7428049)	(1.398771)	(.9513935)	(1.304851)	(.923741)
GC	.4330764	1.236196			-1.74427	-1.939886		
	(1.141743)	(1.15071)			(1.419763)	(1.412929)		
GS	.72245	.7626338			.5828419	.7340653		
	(.8102989)	(.8410144)			(.8802677)	(.8692992)		
OWN	-.1720162		-.83825		.9498761		1.343519	
	(.6853605)		(.6499616)		(.9603989)		(.9389326)	
CNS	-1.552313**			-1.559867***	-.1767619			-.1188945
	(.6666371)			(.5871411)	(.7125713)			(.7327407)
LogD	1.511993**	1.487716**	1.761753***	1.705618***	2.338564**	2.193207**	1.182603*	.6560174
	(.6855239)	(.6991718)	(.4883697)	(.4422821)	(1.038698)	(1.015664)	(.6588138)	(.5803379)
No of Ports	41	41	41	41	44	44	44	44
Observations	82	82	82	82	88	88	88	88
LR χ^2	26.66	20.09	20.51	25.68	6.34	5.34	3.44	1.45
Pro>χ^2	0.0001	0.0002	0.0000	0.0000	0.2749	0.1483	0.1786	0.4845
Log likelihood	-175.61413	-178.90014	-178.68939	-176.10558	-204.72197	-205.21842	-206.16744	-207.16529
Pseudo R^2	0.0706	0.0532	0.0543	0.0680	0.0152	0.0129	0.0083	0.0035

Notes: GS: Southern area location; GC: Central area location; CNS: serving container ships; OWN: Ownership; LogD: logarithm 10 form of the distance to the nearest port. The coefficients with *, ** and *** are significant at 10, 5 and 1 percent, respectively. Standard errors are included in parentheses.

4.4 Robustness analysis

*** COVID-19 impact**

To exclude the possible impact of COVID-19 pandemic on the relationship between seaport competition and efficiency, the data of Vietnamese seaport system in the 2015-2016 period is employed. Table 7 provides regression results and they again support a positive relation between seaport efficiency and competition. The coefficients of national and regional market share are significant. Other variables including GS, GC, and CNS relate to seaport efficiency. The coefficients of GS and GC are positive and significant and this result indicates an impact of geographical location on seaport performance. Specifically, the northern seaports are more efficient than their counterparts in the southern and central regions of Vietnam. Besides, the seaports serving container cargo are more efficient. A comparison of regression results based on the COVID-19 period data (2021-2022) and pre-COVID-19 period data (2015-2016) reveals that the impact of environmental factors can be changed in the context of COVID-19 pandemic. For example, seaports providing container services are more efficient in the pre-COVID-19 period (see Table 7) but they are less efficient in the COVID-19 period in a comparison with other seaports (see Table 5). Furthermore, geographical variables (GS, GC) and ownership (OWN) are significant in the pre-COVID period but they are insignificant in the COVID-19 period. The pandemic disrupted external links and forced port operators to conduct internal solutions on governance, operations and usage of inputs etc., to adapt with the new situation.

Table 7 Tobit regression results on the impact of competition on Vietnamese seaport efficiency using the 2015-2016 data

	Competition at national level				Competition at regional level			
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Intercept	2.877933***	2.414741***	4.410217***	4.826678 ***	3.018323***	2.051379***	4.264588***	4.743954***
	(.731202)	(.5903089)	(.4126503)	(.4190193)	(.7438031)	(.5931552)	(.4066154)	(.4099356)
GC	2.586826***	2.888623***			2.087018***	2.744787***		
	(.7796546)	(.69916)			(.7825903)	(.7332053)		
GS	1.536023**	1.399261*			1.863897**	1.751137**		
	(.720336)	(.7183158)			(.7436855)	(.7479163)		
OWN	.5136508		-1.108422*		.3050046		-1.294344**	
	(.7098311)		(.6623631)		(.704762)		(.6509998)	
CNS	-1.346571**			-1.857677***	-1.796554***			-2.081349***
	(.6379366)			(.5847175)	(.6612211)			(.5768092)
NMS	-10.45095***	-10.45973***	-9.054386***	-9.707252***				
	(3.009804)	(2.761567)	(3.273983)	(2.904694)				
RMS					-21.36098***	-19.18033***	-17.81096**	-21.46776***
					(6.855164)	(6.647129)	(7.195512)	(6.396309)
No of Ports	41	41	41	41	41	41	41	41
Observations	82	82	82	82	82	82	82	82
LR χ^2	33.38	29.00	15.78	22.61	31.23	23.65	14.34	22.66
Pro>χ^2	0.0000	0.0000	0.0004	0.0000	0.0000	0.0000	0.0008	0.0000

Log likelihood	-172.25596	-174.44712	-181.05414	-177.64045	-173.32988	-177.11896	-181.77622	-177.61705
Pseudo R^2	0.0883	0.0767	0.0418	0.0598	0.0826	0.0626	0.0379	0.0600

Notes: GS: Southern area location; GC: Central area location; CNS: serving container ships; OWN: Ownership; NMS: market share at national level; RMS: market share at regional level. The coefficients with *, ** and *** are significant at 10, 5 and 1 percent, respectively. Standard errors are included in parentheses.

*** Scale impact**

Some may wonder the rational of using market share as a proxy of competition. They argue that seaports with bigger size are more advantageous in competing with the others [34], and consequently have a larger market share. On the other hand, when having a larger size the port can utilise the scale effect and achieve a higher level of efficiency. Hence, port size is included in the models to investigate its possible impact on port efficiency. In this study, total berth length is used as a proxy of port size. Table 8 provides results on the relationship between port efficiency and port size with two data sets. Using the data of 2015-2016 period, a positive and significant relationship between port size and efficiency is recorded, while the results show no relation if the 2021-2022 data is used. The results show a different impact of port size when ports operate in the COVID-19 context.

Table 8 Tobit regression results on the impact of scale on Vietnamese seaport efficiency

	2015-2016				2021-2022 (under COVID-19 impact)			
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Intercept	3.377061***	2.280911***	4.494009***	5.042054***	2.748701**	3.341933***	3.28941***	3.660315***
	(.6598382)	(.6598382)	(.4458762)	(.4638999)	(1.10303)	(.8000883)	(.7476718)	(.5893021)
GC	2.022192**	2.760294***			.6136133	.3206855		
	(.8027142)	(.7513227)			(.9427169)	(.8697431)		
GS	1.559101**	1.524966**			.5676554	.7091928		
	(.747316)	(.7589981)			(.9021091)	(.8854958)		
OWN	.1029868		-1.406195**		.7480463		.6630465	
	(.7100382)		(.6519162)		(.9677855)		(.8027142)	
CNS	-1.725276**			-2.145455***	.0735537			.1946218
	(.674257)			(.5833928)	(.7840481)			(.775974)
BL	-.0010342**	-.0009367**	-.0009142**	-.0011792***	-.0011108	-.0010065	-.0011353*	-.0011236
	(.0004144)	(.0004035)	(.0004295)	(.0003897)	(.000721)	(.0006544)	(.0006575)	(.0007175)
No of Ports	41	41	41	41	44	44	44	44
Observations	82	82	82	82	88	88	88	88
LR χ^2	28.17	21.04	12.91	21.00	3.79	3.17	3.20	2.58
Pro>χ^2	0.0000	0.0001	0.0016	0.0000	0.5807	0.3668	0.2021	0.2751
Log likelihood	-174.86029	-178.42353	-182.49067	-178.44534	-205.99723	-206.30718	-206.29071	-206.59924
Pseudo R^2	0.0745	0.0557	0.0342	0.0556	0.0091	0.0076	0.0077	0.0062

Notes: GS: Southern area location; GC: Central area location; CNS: serving container ships; OWN: Ownership; BL: Berth length. The coefficients with *, ** and *** are significant at 10, 5 and 1 percent, respectively. Standard errors are included in parentheses.

5 Conclusion

This research examines the relationship between port competition and efficiency in Vietnam. The results find that port competition relates positively to port efficiency when the market share at both national and regional level and the distance to the nearest port are used as proxies for port competition. With the use of various measures of competition, an increasing trend of seaport competition is recorded over the 2011-2022 period.

To eliminate the possible impact of COVID-19 pandemic on the port competition-efficiency relation, the data of 2015-2016 period is employed and the results also support the positive impact of competition on Vietnamese seaport efficiency. Moreover, the scale effect on port efficiency is proven to be inconsistent; thus, this effect cannot substitute the impact of competition on seaports. The results show a change in the impact of environmental variables on seaport efficiency under the context of COVID-19. Specifically, while location of seaports, ownership and container service provision significantly impact seaport efficiency in the pre-COVID-19 period, they are insignificant in the COVID-19 period.

Based on the empirical evidence of this paper, a number of solutions are proposed to foster competition among Vietnamese seaports and increase their efficiency. First, investments in larger and deeper seaports are encouraged to exploit the scale effect in the port sector. Second, transferring ownership of seaports from government bodies to corporations can attract more capital and advanced technology from private and foreign investors. Third, the government should support the mergers and acquisitions between neighbouring port operators. It is well-known that the Vietnam has many small ports and they are located very closely. Subsequently, they are inefficient as proven by the average inefficiency scores.

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