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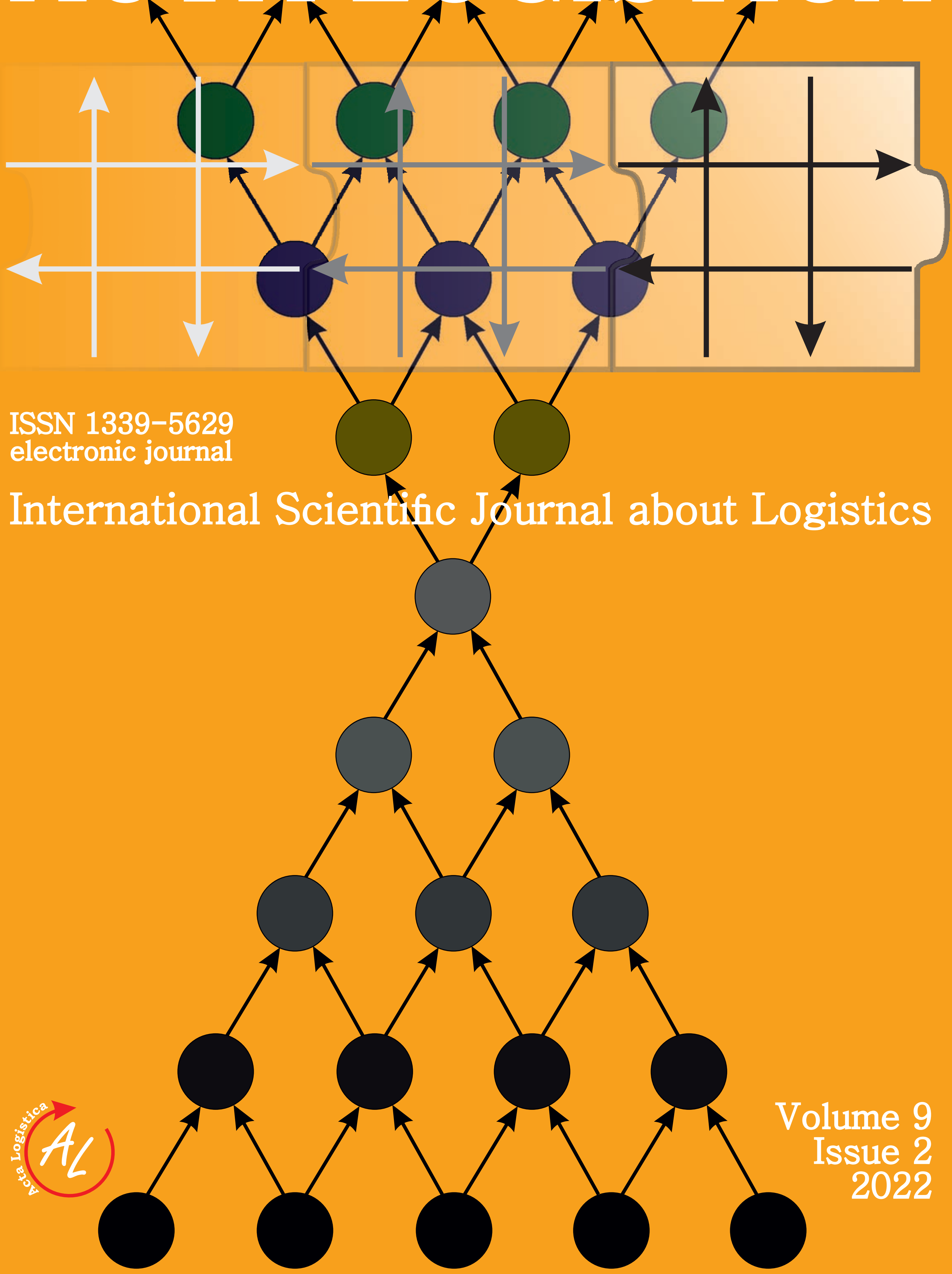

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ANALYSIS OF TRUST VIA THE INTERRELATIONS BETWEEN INTERMEDIARIES IN A DECENTRALISED SUPPLY CHAIN

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Abstract: This article looks at the role of middleman relationships in a decentralized supply chain, considering a three-element structure consisting of an independent supplier, a distributor, and a producer. We study a model based on game theory that allows the analysis of the coordination of the three links, which evaluates qualitative criteria in their supply relationships, distribution, and reception of their operating preferences. The objective of the research is the construction of trust by analyzing the interrelationships of the three links for their consolidation, or not of the supply chain, using the Nash equilibrium, which allows summarizing satisfaction and loyalty throughout the supply chain. The set of Nash equilibria reflects that achieving satisfaction in the interrelationships between them is the main strategy to be followed by companies seeking to promote coordination within their operations. At the same time, we observe that only one agent is sufficient to maintain the flow of materials, i.e., the problem of the free-rider arises between us. In this study, five different equilibria are obtained, of which in four the supply flow continues within the chain, and in one equilibrium the relationship fails.

1 Introduction

The globalization of many industries has strengthened the competition that companies live in their markets, making necessary the improvement of the supply chain's management [1]. Nowadays, production processes take place in different places which implies the involvement of different agents, even from different countries, within the supply chain; this makes necessary to revisit the selection of partners. The literature recognizes the importance of intermediaries to satisfy the requirements from suppliers and producers costumers [2]. So, the benefit of a downstream company relies on the capacity of suppliers and intermediaries to satisfy requisitions. Hence, many companies invest in the development of better relationships with their elements in the supply chain to boost their overall performance and to increase the competitiveness level of the supply chain [3].

Reaching an efficient performance of the supply chain is not an easy task given the interaction of agents with specific objectives. That is to say, there are multiple decision-makers that control the behavior of a supply chain, some of them may have interests in opposition with the objectives of other agents [4]. For example, manufacturers prefer to produce in large batches to reduce installation costs. This increases the number of finished products in inventory, which will eventually increase costs, contradicting the original motivation for such a strategy [5].

It is important to note that member interactions follow the structure of the supply chain. Given the importance of intermediaries, this focuses in the analysis of a decentralized supply chain, which is a structure where agents have to make multiple decisions to improve their interrelationships [6]. On the other hand, Within a centralized supply chain, there is only one decision-maker that controls the activities within the supply chain. The first situation results in local improvement of the interrelations between the members or agents (supplier, distributor, producer), while the centralized system leads to a global development [7]. Our analysis models the decentralised interaction through a game theoretical approach where coordination in the activities between the supplier, the intermediary and the producer contributes to a better location of facilities to fulfil with on-time deliveries.

We analyses a supply chain with three agents: a supplier, an intermediary, and a producer. Considering a simple framework, we assume that producer and supplier may choose between to stay, or not, in the supply chain. So, our equilibrium analysis allows us to identify those scenarios of consolidation, or breaking-up, of the supply chain. Also, we show that the set of equilibria serve to determine the presence, or absence, of trust within the supply chain. Later, we argue the implications of such a factor.

The study of how to generate trust within a supply chain is not new since it a mechanism to improve the coordination between suppliers, distributors, and producers. Nowadays, the globalization of production processes requires the generation of trust for the efficient progress of supply chain members' activities. It is worth to mention that trust acts as a prerequisite to improving the performance of the three most essential processes in the management of the chain: a) flows of materials, b) financial flows and c) information flows. Hence, trust is a precedent to achieve cost reduction via the management. However, it is common that intermediaries do not adequately fulfil their activities generating distrust, which motivates the establishment of positive/negative incentives to induce the adoption of strategies or the fulfilment of specific objectives. We recall that trust generation is crucial since new challenges that supply chains face in the globalization of processes [8].

Our motivation comes from the manufacturing sector where inventory management and on-time fulfilment of customers' requisition may decrease companies' benefits. In [9,10] provide empirical evidence about the impact of intermediaries' actions on the benefits of their clients. Also, they observe that trust is the consequence of the frequency and long-term interactions. So, there is an opportunity area to generate confidence within supply chains. In this sense, game theoretical models provide useful insights into the designing of contracts that establish punishments to those that deviate from a desirable behaviour [1,11].

This paper focuses on analyzing a three-link supply chain through a game theoretical approach. We define the relationship between a supplier, an intermediary and a producer based on the fulfilment of each agent obligations to study the effect of trust in the consolidation or disaggregation of the supply chain, we can exemplify the following, we construct the agents' preferences considering the negative impact of non-compliance over agents' benefits. Moreover, we present the Nash equilibrium analysis in a case where agents only can win, lose or remain indifferent. The equilibria set is not a singleton; non-surprisingly, the disaggregation of the supply chain is an equilibrium, but there are equilibria where the supply chain stands when a single member copes with his responsibilities.

The article is presented in the following order, Section 2 presents the state of the art on the importance of trust within the supply chain and how they interact between suppliers, intermediaries and producers has been analyzed it. So, in section 3 we present a game theoretical that summarizes the possible scenarios that our supply chain faces. Section4 presents the equilibrium analysis, and in section 5 the conclusions reached according to the Nash equilibrium are presented.

2 Literature review

Our article is closely related to analyzing the impact of intermediaries in the success of supply chain activities. In [12], Vieira et al. investigate how the cultural differences between 338 processing plants, in Asia and occidental countries, impact their relationships with intermediaries and the influence of such impact on suppliers' activities. They use structural models to measure the presence or absence of trust. In general, processing plants differences are crucial for the development of a supply chain because their decisions contribute to modify the behavior of previous links in the supply chain. The empirical evidence shows that Asian companies tend to trust more on each other than western companies, [13,14]. In a similar work, [15], MacDuffie, observes that processing plants are the first to punish since intermediaries often forget to evaluate the quality of suppliers' product. It is usual that that quality, from providers products, is taking for granted by the intermediary. However, such negligence generates negative incentives for the supplier activities. That is to say; suppliers have incentives to low the quality of their products since other members of the supply do not implement a complete assessment of their activities.

In recent years, the presence of conflicting objectives within a supply chain, from its participants, indicates that game theory is an appealing methodology to model the generation and impact of trust [16]. In this type of analysis, the structure of the supply chain is essential. In [17], Charvet et al. observe that the number of links in the supply chain has a different impact on the development of the supply chain since each link has specific objectives with different consequences for the other elements of the supply chain. So, the collaboration is necessary to reach a common purpose. However, a collaborative behavior requires different incentives [18].

The most straightforward supply chain, a producer, and a supplier is defined as a centralized structure since the producer also acts as an intermediary to attend final customers. Our paper develops a decentralised supply chain with the presence of an intermediary, who is independent of the decisions that take the producer and the supplier. Also, a decentralised supply chain is often called a three-tier supply chain. In [19], Huang, Huang and Newman analyze the equilibrium interaction of such kind of supply chain following a dynamic approach. They show that inventory levels become a coordination problem since the capacity of some agents to set prices. The coordination analysis motivates non-cooperative [20] Zhao et al. and cooperative approaches [21] Huang and Li.

3 Methodology

We consider a decentralised supply chain with the following players: a supplier, a distributor, and a producer. First, we consider a simultaneous game with incomplete information among these three agents. In this interaction, the supplier produces raw material that is used by the producer. The communication between these two agents relies on the distributor intervention. The central aim of our model is to analyse the consolidation or to break up, of the supply chain. Below, w describe the action that each can take in this supply chain.

Note that suppliers take care of raw material‘s quality, while the distributor is in charge of doing the delivery of the raw material. So, we consider that supplier may supply (D), or not (ND), the good. Also, it is important to recall that distributor’s reputation depends on how the producer evaluates him. So, distributors actions are the four possible combinations between Receive (R), Not Receive (NR), Give (G) and Not Give (NG), i.e., distributor's actions are (R, G), (R, NG), (NR, G) AND (NR, NG). Implicitly, the action (NR, G) assumes that distributor can satisfy producers' requisition using his inventory. Also, the action (R, NG) represents a situation where the distributor wants to increase his inventory levels by no fulfilling the producer's requisition. This behaviour is not unusual since distributor may desire to increase the cost by generating scarcity. Finally, given the features of raw material and distribution service, the produce chooses to continue (S), or not (O), with her relationship with this intermediary. The payoff of each supply chain member depends on the other actions. Table 1 summarises all the possible scenarios that result from the interaction between the producer, the distributor and the supplier.

Table 1 Payments matrix of the supplier, distributor, and producer

		DISTRIBUTOR													
PRODUCER		Receive and Give (R, D)			Receive and Not Give (R, ND)			Do not Receive and Give (NR, D)			Do Not Receive and Do not Give (NR, ND)				SUPPLIER
	Continue (S)	X	A	M	H	I	J	C	LL	E	P	Q	U	Supplying (D)	
		Y	B	N	K	L	Ñ	F	G	Z	T	W	V	Not supplying (ND)	
	Choice of another (O)	X’	A’	M’	H’	I’	J’	C’	LL’	E’	P’	Q’	U’	Supplying (D)	
		Y’	B’	N’	K’	L’	Ñ’	F’	G’	Z’	T’	W’	V’	Not supplying (ND)	

Below, we discuss the relationship between the payoffs, concerning players preferences.

Producer Payments

- **X > X’.** Note that, in this case, choosing another supply chain is unnecessary since the distributor and the supplier fulfil their obligations, (R, D) and D respectively.
- **Y > Y’.** The producer prefers to stay in the supply chain since the distributor fulfils with his requisitions.
- **X > Y.** Although the first link of the supply chain does not fulfil with their obligations, the supplier chooses ND, and the distributor satisfies the producer's requisition.
- **H > H’.** In this case, it is not necessary to choose another supply chain that can meet its obligations, D and even though the distributor is not complying with Do not Give (R, ND), respectively.
- **K > K’.** The producer prefers to remain in the supply chain and even though the distributor is not supplying the product.
- **H > K.** The second link in the supply chain does not fulfil its obligations, the distributor decides not to give ND, does not satisfy the request of the producer. However, the producer decides to continue trusting because the supplier did comply with the demand to give D.
- **C > C’.** Keep in mind that, in this case, it is not necessary to choose another supply chain since the distributor fulfils half of his obligations by not receiving (NR, D) and giving, the supplier fulfils his obligations to give D.
- **F > F’.** The producer prefers to remain in the supply chain since the distributor only complies with giving (NR, D) and satisfying his requisitions.
- **C = F.** Although the first link in the supply chain complies with its obligations, the supplier chooses to give D, but the distributor is not receiving (NR) the

goods. So, the D is indifferent between the action that P chooses.

- **P > P'.** In this case, it is not necessary to choose another supply chain since the supplier fulfils his obligations, even though the distributor does not comply with his activities.
- **T = T'.** The producer prefers to remain in the supply chain and even though the distributor and supplier do not fulfil their obligations respectively.
- **P > T.** Note that the second link in the supply chain does not meet its obligations, the distributor decides not to receive and not give (NR, ND), and the supplier did comply with the demand to give D.

Distributor Payments

- **A > A'.** Because the distributor and the supplier fulfil obligations, (R, D) and D, respectively, in this case, it is not necessary to choose another supply chain.
- **B > B'.** The distributor is complying with the producer's requests, which is why he prefers to remain in the supply chain.
  A > B. The distributor, satisfies the producer's request, although the first link in the supply chain does not fulfil its obligations, because one of the two suppliers chooses ND.
- **I > I'.** The distributor decides to receive and not give (R, ND) falling into a breach of obligations and the supplier fulfils the supplies giving D, in this particular case, the producer chooses to continue the supply chain due to the trust he still has.
  L > L'. The distributor and supplier are not complying with the producer's requisitions, which is why the last opportunity for both are presented. Also, in this situation, he has no more supply options, so he remains in the chain.
  I > L. The second link does not fulfil its obligations, the distributor decides not to give ND, not satisfying the request of the producer. However, the producer decides to continue trusting because the supplier did meet the demand to give D.
- **D > D'.** Keep in mind that, in this case, it is not necessary to choose another supply chain since the distributor complies with half of his obligations by not receiving and giving (NR, D), the supplier fulfils his obligations to give D.
  G > G'. The distributor only complies with giving (NR, D) and satisfying the producer's requests to remain in the supply chain.
- **D > G.** Although the first link in the supply chain fulfils its obligations, the supplier chooses to give D, and the distributor is not receiving (NR), and only satisfies the request of the producer.

- **Q > Q'.** In this case, the distributor does not fulfil its obligations, and because the supplier fulfils his D obligations, it is not necessary to choose another supply chain.
- **W > W'.** The distributor and supplier do not fulfil their obligations respectively. Due to the complexity of replacing the two agents at the same time and the producer prefers to stay within the framework.
- **Q >W.** Note that the second link in the supply chain is not met, the distributor decides not to receive and does not give (NR, ND), and the supplier did comply with the request to give D. reason why the producer remains with them in the supply chain.

Supplier Payments

- **M > M'.** In this case, it is not necessary to choose another supply chain that can fulfil its obligations D, and the distributor to receive and give (R, D), respectively.
- **N > N'.** Although the supplier is not supplying the product to the distributor, the supplier, if it gives and receives the product, the producer prefers to remain in the supply chain.
- **M > N.** Keep in mind that this is the ideal case of a trust scenario because all the intermediaries in the supply chain fulfil their obligations.
- **J > J'.** Even though the supplier fulfilled his obligations, D and the distributor does not do it because he only receives and does not give (R, ND), In this case, it is not necessary to choose another supply chain, due to the effort and commitment of the supplier.
- **O > O'.** The supplier is not supplying the product to the distributor, but he gives takes. Moreover, for that reason, the producer prefers to remain in the supply chain.
- **J > O.** The supplier did comply with the demand to give D to the distributor but decides not to give ND, not fulfilling his obligations with the producer. However, although the second link in the supply chain fails to satisfy its obligations, the producer decides to remain within this supply chain.

4 Results - Example for Nash equilibrium analysis

To illustrate the game that we described in the previous section, we present (Table 2) a payoff matrix considering the values of -1, 1, and 0. If the agent wins, loses or remain indifferent in the scenario described by the corresponding strategies profile.

Table 2 Example of intermediary payments matrix

		DISTRIBUTOR													
PRODUCER		Receive and Give (R, D)			Receive and Not Give (R, ND)			Do not Receive and Give (NR, D)			Do Not Receive and Do not Give (NR, ND)				SUPPLIER
	Continue (S)	1	1	1	1	1	1	1	0	-1	1	0	-1	Supplying (D)	
		-1	-1	0	0	-1	0	0	1	0	-1	0	0	Not supplying (ND)	
	Choice of another (O)	0	0	1	-1	0	1	-1	1	-1	0	0	-1	Supplying (D)	
		-1	-1	0	0	-1	0	0	-1	0	0	0	0	Not supplying (ND)	

5 Discussion - Nash equilibrium

To know the equilibria of the payment matrix of the supplier, distributor, and producer, we calculate the best response of each player. We find five Nash equilibria in the previous game, that we discuss below.

1. (S, (R-D), D)

The producer follows (S) or continues in the supply chain because the distributor receives (R) the product and gives it (D) and the supplier starts giving (D) the raw material. This first equilibrium could be understood as the full trust between the three players as they all give and receive and continue with the same structure. This balance is considered natural because all intermediaries fulfil their activities effectively and reciprocally.

2. (O, (R-D), D)

The producer does not follow (O) or does not continue in the supply chain, although the distributor receives (R) the product and gives it (D) and the supplier starts giving (D) the raw material. In this second equilibrium, it is observed that the producer changes or do not continue in the structure of said chain, although he is receiving the product, however, if confidence is generated between the supplier and distributor considering continuing with the same structure between said players. We do not omit that the result is surprising because the first two intermediaries comply without any problems that the producer requests and he decides to change the structure of the chain together with them. However, it is a reflection of what happens in real life.

3. (S, (R-ND), D)

The producer follows (S) or continues in the supply chain because the distributor receives (R) the product, but does not give it (ND) and the supplier starts giving (D) the product. In this third equilibrium, we observe a proper interrelation of coordination between the supplier and the producer because the first decides to give the goods and the last continues with supply chain structure even though the distributor, receiving the product, does not deliver it generating an area of opportunity to improve. In the same way, this balance surprises the result or decision of the producer who decides to continue the relationship with the distributor, due to the failure of the same, but this reflects that in reality, many processes need particular or specific distributors. Therefore, they take the attitude of imposing priorities and not coping, and for them arise for both intermediaries areas of opportunity.

4. (S, (NR-D), ND)

The producer follows (S) or continues in the supply chain because the distributor does not receive (NR) the product, but if he manages to give (D) the product and the supplier starts not giving (ND) the raw material. In this fourth equilibrium, it is observed that confidence is generated between two players: distributor and producer, even though the supplier starts poorly or with a breach, as happens in a particular case of industrial life. Alternatively, the fantastic reflection of the total commitment that the distributor has a policy not to fall into default and to wear down the relationship with his final client. In this case, the producer because the relationship he has with the supplier is a complete loss.

5. (O, (NR-ND), ND)

The producer does not follow (O) or does not continue in the supply chain, as the distributor does not receive (NR) the product and consequently does not give (ND), and the supplier starts not giving (ND) the product. In this last equilibrium reflects that the behaviour of intermediaries are natural because it is observed that there is no penalty or punishment for any player because there are breach relations between them.

6 Conclusions

Our article qualitatively analyzes the relationships of intermediate actors within a supply chain using the Nash equilibrium. The theoretical analysis of the game contributes to establishing five equilibria within a framework of actions by each of the members immersed in the said chain and how they impact its behavior and general structure.

The first equilibrium could be understood as full trust between the three players since they all give, receive, and continue with the same structure. This balance is considered natural because all intermediaries carry out their activities effectively and reciprocally. The third equilibrium reflects a surprising result or decision on the part of the producer who decides to continue the relationship with the distributor, despite the failure in the delivery of material from the latter, due to the particularity or specificity of his services. This gives us guidelines for the investigation of the particularities in the processes or services of the distributors and the tolerance levels of the producers to continue with the relationship. The fourth equilibrium identifies the efforts of the distributor to supply the producer even when the supplier does not comply, denoting the total commitment that the distributor has with a policy not to fall into default and wear down the relationship with its end customer.

In this way, we observe factors that exert a positive and motivating effect on trust and loyalty, as well as incentives for freeriding. In other words, although most of the studies focus on motivating aspects, our analysis identifies that the members of the offer pursue the maximum benefit by taking advantage of the trust that others place in them.

However, the second equilibrium reflects a change in the chain structure due to non-compliance by the producer, while still surprising the producer's decision, despite the distributor and supplier's compliance. However, it is a reflection of what happens in real life. Therefore, it gives way to the future qualitative and quantitative study of the reasons why a producer, despite having efficient supply services, decides to break with the supply chain structure. A five equilibrium shows the disinterest and lack of commitment on the part of the three players. This is motivated by the lack of penalty and/or punishment for the players because there are breaking relationships between them.

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ASSESSMENT OF THE URBAN FREIGHT REGULATIONS IMPACT ON THE TRANSPORTATION COST

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Keywords: urban logistics, modelling, tariffs, vehicle carrying capacity, local tax regulations for transportation.
Abstract: The paper will investigate the impact of the vehicle carrying capacity to which the local tax is applied on forming the cost of delivery. The cost of 1 ton of freight under different tax scenarios is estimated in the paper: without tax 0, with fixed tax – 10% and with progressive tax from 0 to 75%. The greatest effect on reducing the vehicle's load capacity during urban deliveries showed a progressive tax. The developed regression model allows determining the cost of transportation of 1 ton of goods depending on the technological parameters of transport operations, the costs of the transport (logistics) operators to perform these operations, and local tax regulations for transport. The application of the model makes it possible to regulate the use of vehicles of a given capacity by the local administration. In contrast to the strict prohibition on the establishment of traffic signs, the use of a progressive tax by the local administration makes it possible to regulate traffic structure by economic methods. Exploring of influence local tax regulations on transportation will lead to the sustainability of the cities in order to provide GREEN technologies.

1 Introduction

Managing the development of logistics is a vital task for industries and transport focused on the sale of goods and for entire retails, and other related industries focused on the livability of the cities. Researchers agree that the local policy of transport services is a very important stage in freight flows distribution, as it affects the final cost of goods, transport and freight flows, transport time, etc., in the cities [1,2]. Analysis shows expenditures on transportation services on the distribution stage of finished products in the world have increased by 12% since the beginning of the COVID-19 pandemic and, on average, account for 10% of sales [3]. However, the authors note that distribution costs continue to rise [4]. At the same time, the influence of traffic flows on the comfort of movement in cities has increased [5]: the number of private cars has increased, especially commercial vehicles – like HLV. In order to reduce the impact of these factors, urban logistics tools are used. One of the main factors that can be managing the attractiveness of the last-mile option is the cost of shipment. Transport policy regulations usually have a direct impact on the cost factor. The complexity of such regulations is related to the variety of stakeholders who become members of urban freight and their numerous connections and the very object of pricing in supply chains. Such objects are the cost of transport or logistics services from one side and external costs of society for this type of service from the other side. Depending on the conditions of transport regulations, the cost structure of the transport operator and the method of pricing in the freight transportation market change, which determines the volume of services provided to them. Exploring the influence of city tax regulations on the price and amount of transport or logistics services becomes a high-value task for theory and practice to achieve well-known concepts of Smart and Livability cities. Such regulation leads to stimulating greener services to reduce transportation by high capacity vehicles and internal combustion engine utilisation and towards EV or ect., sustainable scenarios in cities. Local tax regulations for transportation can be one of the authorities' options to manage transport policy and achieve marked goals. The aim of this paper is to assess the urban freight regulations into Ukraine transport policy and establish their effects on the transportation cost for Green city solutions.

The research includes the next steps:

- Literature review
- Methodology of research;
- Development of the Urban freight rate model including local transport tax;
- Determination of the influence value of urban freight rate on delivery value;
- Discussion and Conclusions.

2 Literature review

2.1 Urban freight efficiency

The transport participant is a separate link in the movement of goods in space and time from the places of origin to its consumption. Promotion of any freight flow is carried out according to the certain technology of transportation inherent in the given goods. Modern technologies aim to reduce transportation costs [6], zero-emission [7], sustainable transport development [8], etc. At the same time, the existing goals do not aim to study the connection between transport process technology and consumption [9]. This interaction is due to the use of steady demand in urban freight. The change in cost affects the demand and supply of transport in urban freight. Solving the problems of managing the cost of transport services will ensure the sustainable development of the city freight operator and the sustainable development of the city's transport system, which requires the use of new methods and technologies for managing them.

Among the models that determine the efficiency of transport services, there are models related to the evaluation of transport services by customers [10] and the own assessment of transport service carriers [11]. Such models include a large number of parameters of customer service quality, in other words, the requirements of transport services consumers to their service. Determining the source information for the calculation of this model is a difficult step because it requires data on the work of the carrier, which may not be available. Modern methods and models help to facilitate the functioning of transport in logistics systems as well as in other industries [12-14]. The key role of transportation in logistics is explained not only by the greater share of transport costs in the total logistics costs but also by the fact that without transportation, the very existence of material flows is impossible.

Analysing the work of transport operators of shipping goods, it can be noted that one of the main conditions for ensuring the efficiency of these systems is to meet the demand at the lowest cost. To do this, optimal routes are organised, the necessary brands of vehicles in terms of carrying capacity are selected, transport work is coordinated with loading and unloading posts, etc. [15]. Each logistics system in the process of its operation depends on its costs [16]. Analysing the structure of logistics costs, we can identify ways to improve the efficiency of the logistics system, one of which is the optimisation of delivery costs depending on the load capacity of the vehicle used [17]: Light commercial vehicles (LCVs) with grouse vehicle weight (GVW) less than 3.5 ton; Intermediate Light commercial vehicle (ILCV) with GVW of 3.5 to 8 ton; Intermediate commercial vehicle (ICV) with GVW of 8 to 10 ton; Medium commercial vehicles (MCV) with GVW of 10 to 15 ton; Heavy commercial vehicle (HCV) with GVW of 16 ton and above etc. The paper will investigate the impact of the vehicle carrying capacity to which the local tax is applied on the formation of the cost of delivery.

2.2 Transport policy regulations

The transportation cost affects the final price of goods to end-consumers, as well as it is add-value. The cost of transportation is often fixed in the urban environment by different operators. Constant technology provides sustainability and resilience of urban freight. But, variations of technological parameters (for instant, vehicle capacity changes) support changes in costs and urban freight rates, respectively. As the theory and practice of research shows [18-20], variation in the carrying capacity of a vehicle in cities is not a very popular management solution in Europe last years. Authors leave it constant due to several reasons for this:

- no other options in the fleet of the logistics operator. As a rule, the fleet consists of the same brands and typical vehicles that work according to a given technology. It is important to note the ease of maintenance of one brand of vehicles for the transport operator [21,22]. The increase in brand variations and vehicle carrying capacity will increase their maintenance cost, which is not always rational from the point of view of the revenue generated.

- lack of complete information and experience in the use of vehicles of different carrying capacity. The problem is related to the difficulty of predicting the operational performance of vehicles. Technological changes usually affect not only transport but also other participants in the supply chain: shippers and consignees [23];

- strict restrictions on the weight of the vehicle used in cities. Prohibition of HLV entry into cities or it is separate areas, historical centres, etc., reduces the possibilities by varying the carrying capacity of vehicles. Additional restrictions are imposed by «time window» and «green vehicles» [24];

- lack of a second chance. Buying a vehicle comes with a cost and should be justified enough. An active business does not have sufficient funds for experiments and wrong decisions. Therefore, any changes will be considered from many angles for a durable solution [25].

Mostly in CIS countries, scientific schools for the development of delivery technology determine the optimal vehicle's capacity for each delivery scenario or logistics system functioning [26-29]. During vehicle selection, it is

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operation indicators, specification, speed and delivery times, level of goods storage, the convenience of transportation, regularity of service, the complexity of service and other quality characteristics, the spatial location of transport infrastructure, level of competition in the transport market and other factors should be taken into account. In this regard, there are some questions about determining the rational type of vehicle and delivery scenario [29]: traditional trucks with internal combustion engines, electric cars, trucks, «passing cars» (carsheering), «passing deliveries» (crowdshipping)), drones [30].

Transport operations in logistics systems have a number of parameters: turnaround time, route length, tour quntity, quntity of depots and recivers, the required quntity of vehicles, etc. [31]. Management of this indicators makes it possible to increase the efficiency of transport services and, as a consequence, the scheme of goods distribution [32]. Transport operator operations associated with its implementation costs due to certain parameters. In a coherent analysis of the chain, it is proved that the parameters of a single transport operator can have a significant impact on the end-prize of the goods.

Modeling and simulation techniques are widely used to handle many variations. They allow to transfer all the necessary properties of real objects to abstract systems. This approach ensures the integrity of the system and allows to explore all scenarios for a long-term decision.

3 Methodology

3.1 Model description, limitations, collecting the data

The task of urban logistics can be solved on the basis of establishing a rational load capacity, which provides a minimum cost of goods delivery. The establishment of local tax regulations for transportation capacity allows you to adjust costs (increase or decrease) depending on market conditions and the need to use vehicles of a certain capacity in the transport system of the city. It is possible to obtain such an effect by applying transport regulation in the formation of transport rates.

This approach leads to a set of interrelated functions, the implementation of which provides the desired effect in achieving the goal of functioning of the urban transport system and logistics operator as an integral system and not its individual components. These aspects cannot be considered in isolation but should be based on their interconnectedness, and the effectiveness of the decisions taken should be assessed in the light of the interests of all stakeholders involved in the delivery of the goods. To study urban freight regulations impact on the transportation cost it is necessary:

1. Set up the data source and system limitations.
2. Build a mathematical model of the transport services cost depending on the parameters of time and distance after taking into account local tax regulations for transportation capacity.
3. Establish the impact of changing the value of local tax regulations on the cost of delivery. Consider zero (tax-free), fixed, and progressive local tax regulations for transportation capacity.

To study the logistics chain functioning boundaries of the system, number of participants and their interaction was determined. The process of goods delivery on Kyiv, Kharkiv and Mariupol example was analysed. Due to numerous number of technologies the grocery food flow was applied for further analysis. The statisticla records from indystry was obtained and personal obsevations at logistics (transport) operators were made. The following delivery attributes that characterise retail networks and routes were selected for the study: time on the route when servicing the retail network; the distance travelled by the vehicle during maintenance. Such parameters are decisive for the formation of the transportation cost according to [22,27]. In addition, local tax regulations for transportation capacity and vehicle carrying capacity were established. The collected range of variation of these parameters is given in Table 1. The number of experiments was determined from the nomogram of sufficiently large numbers on the basis of the permissible error $\varepsilon = 0.05$. The Pearson's fitting criterion (χ^2) for confidence probability $P = 0.95$ and permissible error $\varepsilon = 0.05$. was estimated.

Table 1 Data variation range

Parameter	Units of measurement	Minimum value	Maximum value	Average value
Total time of transportation in retail network	hrs	1.55	23.00	6.00
Total distance of transportation in retail network	km	2	2250	25
Load capacity of the vehicle	t	2	22	10
Local tax regulations for transportation capacity	%	0	45	20

3.2 Model description, limitations, collecting the data

Analysis of the costs of the transport (logistics) operator indicates their dependence on the technological indicators of service time and total mileage on the routes. Also, the total cost of transporting goods consists of variable costs ($C_i^{TO\_зм}$) and fixed costs ($C_i^{TO\_пост}$):

$$C_i^D = C_i^{TO\_пост} \cdot T_i^{TO} + C_i^{TO\_зм} \cdot L_i^{TO} + T_i^{\%TO} \rightarrow min \quad (1)$$

where $C_i^{TO\_пост}$ – fixed transportation costs, UAH/hour; $C_i^{TO\_зм}$ – variable transportation costs, UAH/km; $T_i^{\%TO}$ – local tax regulations for transportation, %; L_i^{TO}– total distance of transportation in retail network, km; T_i^{TO}– total time of transportation in retail network, hours.

In addition to the costs of the transport (logistics) operator, local tax regulations for transportation have been added to the model as a component of the city logistics balance. Increasing the carrying capacity of vehicles reduces the delivery cost of 1 ton of goods [33]. The use of heavy-duty vehicles has a greater impact on the environment and other external costs than LCV or ILCV. The introduction of the tax will stimulate operators to operate vehicles with lower capacity and as a result will move towards a sustainable scenario of transport development in cities, Figure 1. 3 scenarios are considered: Scenario 0 – current situation, tax is not applied; Scenario A – tax is fixed at 10% for all types of vehicles, Scenario B – tax is progressive and consists of 0% for LCV, 10% for ILCV, 25% for ICV, 50% for MCV, 75% for HCV.

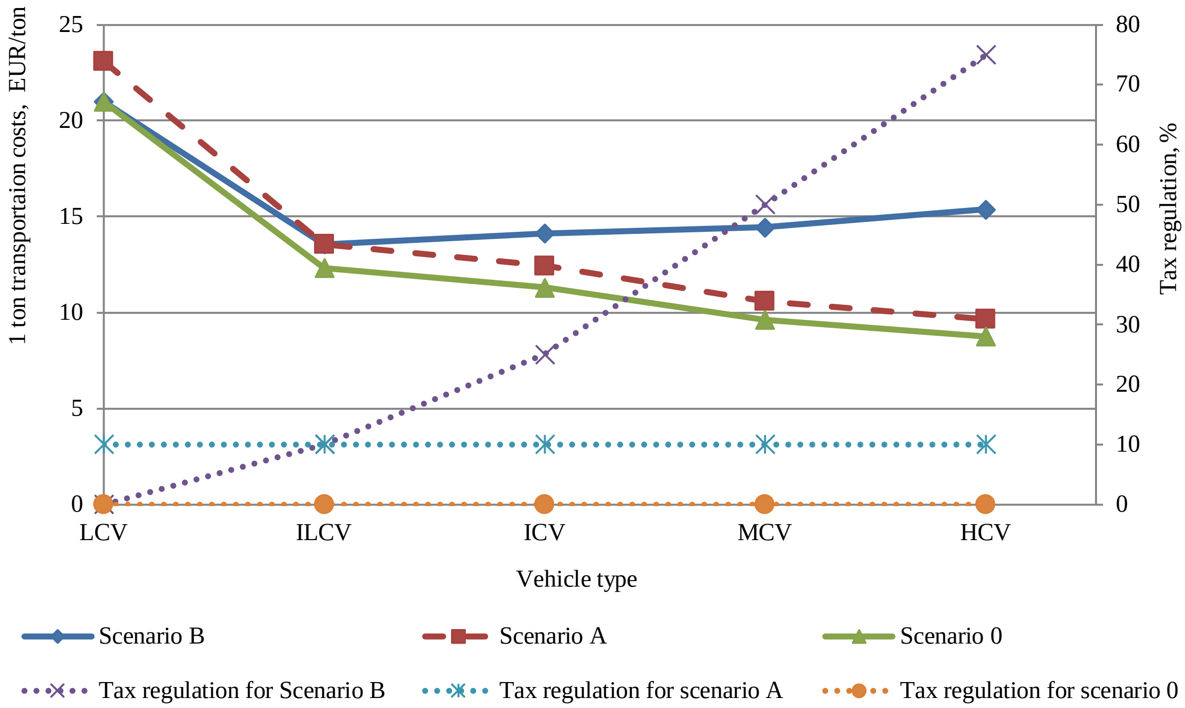

Figure 1 Scenario of a single ton transportation costs and tax regulation on type of vehicle, average demand of retailer is 1 ton

From the graphs (Figure 1) we see that the increase in the carrying capacity of vehicles leads to a change in the cost of transportation of 1 ton of goods. Transport costs and tax regulation are considered as a component of the goods delivery cost to members of the retail network. Such a change in indicators is interdependent. Initially, the increase in load capacity from LCV to ILCV affects the reduced cost of delivery, and with further growth there is a slight increase. The relationship between the indicators can be explained by the following circumstances. Increasing the load capacity of vehicles to a certain level helps to reduce the costs of the transport operator for a certain amount of restocking in system. Rational is such a capacity that minimises logistics costs per unit of delivery. With the considered parameters of the distribution scheme, it is advisable to use vehicles with a carrying capacity of ILCV, Figure 2 and Figure 3.

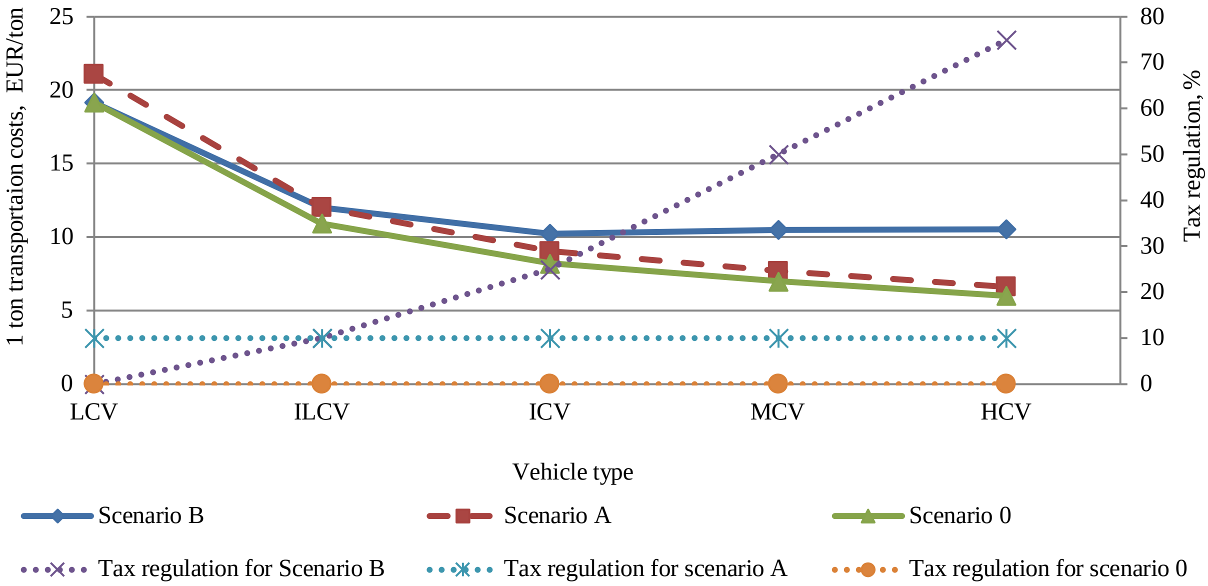

Figure 2 Scenario of a single ton transportation costs and tax regulation on type of vehicle, average demand of retailer is 3 ton

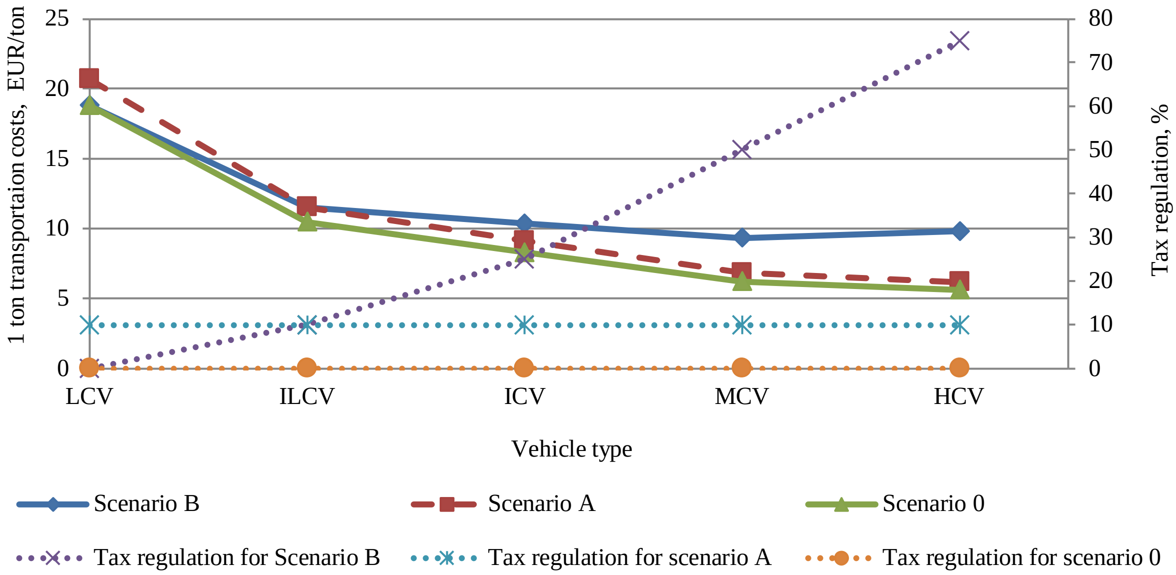

Figure 3 Scenario of a single ton transportation costs and tax regulation on type of vehicle, average demand of retailer is 5 ton

Analysis of Figure 1-3 showed that there is such a rational load capacity of the vehicle, which provides a minimum cost of delivery in accordance with local tax regulations. Increasing demand of delivery to 3 tons at Figure 2 and up to 5 tons causes an increase in the rational load capacity to ICV and MCV respectively.

Using the obtained data, the influence of each considered parameter on the cost of delivery was estimated. Using correlation-regression analysis, a model was obtained for the change in the average cost of one order fulfilment when servicing a retail network, taking into account local tax regulations for transportation capacity:

$$TSC_i^D = \frac{3{,}833 \cdot \sqrt{L_i^{TO}} + 0{,}28 \cdot (T_i^{TO})^{1{,}4} + 217{,}71 \cdot \left(\frac{T_i^{\%TO}}{100}\right)^2}{Q_i}. \quad (2)$$

The regression coefficients were calculated by the method of least squares. The results of model evaluation are given in Table 2, Table 3.

Table 2 Model evaluation results

Indicator	Value
Students' criterion:	
tabular	1.97
estimated for total mileage	2.20809
estimated for the total service time	2.00112
estimated for local tax regulations for transportation capacity	5.44039
Fisher's index:	
calculated	3.88
estimated	109.89
Correlation coefficient	0.9463
Determination coefficient	0.8956
Average approximation error	8.34

The results of statistical evaluation prove that the obtained model is characterised by a sufficiently high information capacity, as evidenced by the estimated value of Fisher's index 109.89, which exceeds the tabular 3.88. The estimated Students' criterion is equal to 2.208 for the total mileage, 2.00 for the total service time, 5.44 for the rate of return of the transport operator, tabular 1.97. The degree of correlation is 0.94. The average approximation error is 8.34%. Therefore, we can conclude that the obtained model adequately describes the dependence of the change in the average cost of one order when servicing the distribution network on the total mileage in the supply system, total service time, local tax regulations for transportation capacity.

Table 3 95.0 %-confidence intervals for estimating model coefficients

Parameter	Calculated coefficient	Standard error	Lower border	Upper border
Total mileage in the supply system	3.8329	1.73585	0.3741	7.2916
Total service time	0.2797	0.13980	0.0011	0.5583
Local tax regulations for transportation capacity	217.71	40.0174	137.97	297.44

Analysis of the model (2) of the delivery cost, taking into considering local tax regulations for transportation capacity showed that with increasing total mileage, total service time and the amount of tax increases the average cost of one order.

Obtained model can be used for estimating TSC for Ukrainian cities in order to facilitate reducing transport problems and provide necessary sustainable regulations. The results were obtained was disseminated on 3 cities which have different size, populations and other parameters. Obtained data define limitations of suggested method in order to data set was observed and collected statistics. The results allowed modeling the TSC for logistics (transport) operator for some adjustments in estimating the limits of business (taxation system), type of goods, distribution zone traffic regulations, green vehicle utilisation and other. This information can be initial data for further research and developing more specific model for each type of scenario.

4 Conclusions

The paper estimates the costs of 1 ton of freight under different tax scenarios: without tax 0, with fixed tax – 10% and with progressive tax from 0 to 75%. The greatest effect on reducing the carrying capacity of the vehicle during urban deliveries showed a progressive tax. The size of the tax can be changed depending on the conditions of application (city, population, level of motorisation, etc.). The current values of taxes applied in the work refer to large cities of Ukraine such as Kharkiv, Dnipro, Odessa, Kyiv, Lviv, Mariupol. The article simulates the volume of retailer demand in the delivery system. The increase in the volume of material flow in the logistics chain causes an increase in the rational carrying capacity of vehicles.

The proposed model allows to determine the cost of transportation of 1 ton of goods depending on the technological parameters of transport operations, the costs of the transport (logistics) operator to perform these operations, and local tax regulations for transport. This method takes into consideration the parameters of the participants in the process of transportation and demand, reflects the relationship between the parameters of supply systems and local government. Based on this, it can be argued that the cost optimisation of transport operator leads to increased efficiency of logistics which support the goal of paper to investigate the impact of vehicle carrying capacity to which the local tax is applied on the formation of the cost of delivery.

The application of the model makes it possible to regulate the use of vehicles of a given capacity by the local administration. In contrast to the strict ban on the establishment of traffic signs, the use of a progressive tax by the local administration makes it possible to regulate the structure of traffic by economic methods. The transport (logistics) operator decides to pay a high tax or change the delivery technology and not pay the local tax. Reducing the vehicle's load capacity leads to a decrease in the volume of delivery and an increase in the frequency of deliveries, which positively affects the size and value of inventories of retail participants – reducing it. The funds received by the local administration as a result of the application of such a tax can be used to ensure the sustainable development of transport infrastructure or to stimulate investment in green logistics, etc.

Effective logistics management occurs when an optimal balance is established between logistics costs and local tax regulation for the use of different types of transport. For the consumer, not only the final price of the product is important, but also the level of service, accessibility and convenience of movement, and care for the environment. The use of LCV, ILCV reduces emissions and congestion on the roads and contributes to the sustainable development of society.

Thus, we have focused on one basic principle of creating persistence of delivery in green cities. We conclude that an effective supply chain delivery scenario is not based on an «entirely new» skill set. Instead, efforts to create more sustainable practices contribute to continuous business improvement. The development and fine-tuning of urban logistics management is a largely continuous process of improvement based on past experience and new research.

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IMPROVING THE EFFICIENCY OF TRANSPORT SYSTEM LEGAL REGULATION IN THE CONTEXT OF GLOBALISATION: PECULIARITIES OF THE NATIONAL ECONOMY

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Abstract: The study aims to analyse problems associated with the legal regulation of the transport system. The study is based on the international and domestic ranking of logistics performance. It also takes into account the economic consequences of world internationalisation to optimise logistics performance (this includes the transportation and legal aspects) under the Transport Development Strategy of the Russian Federation until 2030. The study relies on a systematic approach to systematise legislative, economic and social information and thus create an integral system of transport communication. The review of the legal regulation issues surrounding the transport system showed the following supply chain problems: weak policy coordination and a low level of digitalisation. These problems result in low-quality service and low transparency in legal matters. According to the results of this study, the integration of the world's best practices into transport communications will improve economic efficiency. The scientific novelty of the study is a practical tool to improve transport system efficiency in the context of globalisation, considering the characteristics of the national economy.

1 Introduction

Global supply chains are complex and involve multiple stakeholders, most of whom are in different countries and sometimes on different continents. This makes chains vulnerable to disruptions, as was well demonstrated during the COVID-19 pandemic outbreak in 2020 and the nationwide blockages that followed it around the world. According to the Supply Chain Vulnerability Index [1], the U.S. and U.K. rank first and second most vulnerable to supply chain disruptions. Australia, France and Russia come next. The index also shows that Germany's supply chains are the least vulnerable in 2021, with China, South Korea, Ireland and the Netherlands in the top five, indicating that their supply chains remain secure. Tang, 2022 notes that supply chain management is an integral part of coordinating operations that focus on all elements: from creating a product or service to providing that product or service at the best price and in the best time. As market conditions have changed, many shippers and transportation providers have been forced to rethink their supply chain strategies within national jurisdictions [2].

1.1 Literature review

Transport communications link companies around the world and represent a necessary precondition for a country's integrity and its integration into the global economy through external economic activity, focusing on new opportunities to overcome the effects of the coronavirus pandemic. In this regard, the transport system relates directly to the economy and the social sphere [3, 4]. The transport system is a network of freight carriers and shippers, government transport agencies, metropolitan planning organisations, freight advisory councils and other organisations interested in establishing a sustainable and reliable shipping system [5]. Any state's transport policy is characterised by national priorities at the micro and at the macro-level [6]. A competitive transport system must have the following characteristics: be economically, environmentally and socially sustainable; be able to effectively recover from natural disasters; have a developed and reliable IT-infrastructure [7]. Driven by innovation, socially-oriented economies shift towards service logistics [8]. Logistics refers to the storage and transportation of goods within the economic system. Logistics is closely connected with management as proper management influences positively on logistics. As for supply chains management, it is the process of realising the flow of products from just materials to complete production with minimal expenses. In general, supply chain management includes demand planning, supply planning, production planning, stock management and logistics [9]. In this regard, transport is a service that serves the supply chain. There are four primary ways of transportation: sea, rail, road, and air. They can be used either individually or in combination with each other. This requires companies to possess key factors: a skilled workforce, a permanent talent pool and a proper employee retention policy by investing in internal resources [1].

A post-pandemic coronavirus country-by-country audit of the transportation industry (Australia, Great Britain, Germany, Russia, Panama, Peru) [10] showed that as the global movement of goods and people resumes, the situation of the transportation system stabilises in the long term. Russia, among the countries analysed, is the largest country in the world with an area of 17.1 million km² [11] and by population - ninth largest country out of 245 countries in the world [12]. Consequently, the country requires a high level of trade and a developed transport industry in order to remain prosperous in the global community. The crisis of 2014 caused an economic downturn and, consequently, a decrease in imports and exports, which negatively influenced on freight traffic. After the crisis the transport sector began to slowly recover in 2015. In 2019, it amounted to 102.8% versus 99.1% in 2014 [11]. The transport and logistics industry accounts for approximately 6.3% of Russia's GDP. In comparison with the EU countries, this figure constitutes 2.7% on average [13, 14]. Hence, one can argue that the Russian economy launched a growth regime. Freight transportation in a supply chain becomes a high priority. At the same time, e-commerce creates additional opportunities for logistics services. One of them is the increasing volume of freight traffic. The main way to deliver goods in Russia is road transportation [15]. It accounts for 70% of the total freight turnover. Railroad transportation ranks second. Moreover, Russia relies on airways and seaways to move freight across borders. For instance, seaway transport accounts for nearly 60% of international freight traffic, mainly because of the geographical location of the country. It is bounded by the Pacific Ocean and three seas - the Baltic Sea, the Black Sea and the Caspian Sea [13]. The share of the Russian e-commerce market in 2019 was 22%. According to experts, it will tend to expand. At the same time, the largest share in digital retail sales belongs to the European Union countries (65%) and China (48%) [13]. In this regard, some issues become of high importance. These include the policy environment of the freight transportation in a supply chain regulated by the national legislation [3].

The rule of law of transport legislation is declared in the Russian Federation Constitution [16: 71]. Analysing the legal framework for the transport sector in Russia, Aristov [17] underlined the three primary regulatory documents:

- The Decree of the President of the Russian Federation on the National Security Strategy of the Russian Federation;
- Federal Law on Road Safety;
- Federal Law on Transport Safety [17].

Thus, economic security at the national level is presented in the Russian Federation Strategy [18]. The safety of transport activities is regulated by the Federal Law on Transport Safety [19]. The Federal Law on Road Safety regulates the issues concerning the interaction of vehicles and transport process participants are regulated by the State Duma [20].

The policy environment includes the ordering of all subjects' relations without exceptions through the usage of legal instruments [21]. Because the world is becoming internalised in the context of globalisation, developing the transport system within the country and adjusting national legislation to global changes become a priority. The main task of the transport infrastructure sector in Russia is to achieve maximum growth of the transport market. It should meet the needs of the national economy. One way to reach this goal to establish an effective internal logistics environment. The Ministry of the Transport of the Russian Federation is the executive body responsible for implementing government policy and legal regulation in the field of transportation under the Transport Development Strategy for the Period until 2030 [22, 23].

In recent years, the freight transportation sector in Russia comprises of five directions. These are road (67.6%) and rail shipping (16.7%), pipelines transport (14.3%), seaways transportation (1.8%) and air (0.1%) [13].

Taking into account the above, it can be stated that studies on legal regulation concerning transportation do not consider the practice-related issues, and in most cases resolve theoretical issues. The identified research gap is filled in this study by applying systematisation to the political aspects of forming a state position to create conditions for transport system development and determining how to improve the legal regulation of freight transportation to enable efficient supply chain management.

1.2 Problem statement

Any country has a strategic document establishing a model of actions with the view to achieve a global developmental goal. To be competitive, a country must have a viable economy. Nowadays, Russia's transport sector is in transition and needs a policy behind it that will improve the general approach to transportation of goods in a supply chain and align it with the global trends.

Transport policy should avoid mobility limitations. It must cover a range of social and economic issues. Transportation is an underlying sector of the national economy. A competitive transport infrastructure is needed both for the internal market to ensure economic and social unification and for the external one, especially in the field of commerce.

The purpose of the study is to analyse the problems of the legislative framework for the freight transportation in a competitive global supply chain.

Research objectives:

1) monitoring international logistics effectiveness in different counties;

2) analysing the effectiveness of internal logistics and legislative stability in the Russian Federation;

3) identifying strategic objectives of the Transport Strategy within the national economy.

2 Methodology

In this study, the transport system is considered from the perspective of the regulatory framework of logistics. The theoretical part is built on the concepts of Aristov [17], Platzer [6], and Tang [24]. Initial empirical base - data of the World Bank, 2020 and reports from the official website of the Ministry of Transport of the Russian Federation, 2021. The study relies on the following methods: monitoring, analytical analysis, comparative analysis, normative method, and systematic approach. The latter is a core research method in this study. It helped systematise the legislative, economic and social information to create an integral system of transport communication.

Initially, this study monitors the current state of the logistics system of countries around the world [25], which consists of six evaluation criteria: customs administration, transport infrastructure, international transport, logistics quality and competence, tracking of cargo transportation in the supply chain, timeliness of cargo delivery. A summary assessment of the six criteria constitutes a logistics performance index (LPI), using the geometric mean method: $G=\sqrt{}(x\&X_1\ X_2X_3.)..X\_n$, where $X_i \geq 0$ for $i=1,2,\ldots n$. LPI inde□ covers 160 countries of the world with different levels of economic development according to the World Bank classification (Atlas method). The frequency of the study is once every two years. The result is a ranking table of logistics systems development of the countries on an international scale as of 2021. The ranking table includes countries' scores and ranks broken down into three positions:

- I position - ranking leaders (LPI index corresponds to the highest value of this index equal to 100);
- II position - countries with average positions in the rating (LPI index is within average values, 45-55), which indicates the opportunities for advanced development in comparison with other countries of the world;
- III last positions in the rating - the countries with the lowest scores on the LPI index.

The second stage is a detailed analysis of the logistics constraints within the regulatory framework between the country with the most stable indicators of the internal logistics environment (Russia) and a benchmark country in this industry with high indicators (Germany). Logistics performance was measured against four main criteria for assessing internal logistics performance (LPI) [25]: border procedures; infrastructure; services; process efficiency and time; implementations and developments, which increase supply chain reliability. The ranking of the results is identical to the LPI composite index. The result of this stage is a comparative table of the characteristics of domestic logistics systems in Russia and the leader in this industry (Germany), which allows one to work through the identified logistics constraints through the study and use of best practices.

At the third stage, given the data of monitoring and comparative analysis, a structural-logistics scheme (SLS) is formed, aimed at improving the approach to organising a transport system at the macro level in the context of globalisation. The information base for the SLS is the Transport Development Strategy to 2030 of Russia [3]. The structure of the scheme includes two stages of change: fundamental factors affecting the national economy and fundamental changes in the context of globalisation. Together, the stages systematise the economic, social and legal regulation of the transport system into a single graphical model, which allows one to present transport system development at the macro level in a holistic and accessible way.

Limitation of the study. The study is focused on a detailed analysis of the national economy and transport system of Russia, which narrows the study subject and makes it limited.

3 Result and discussion

An analytical review of case studies has shown that transport logistics is a driving force behind the competitiveness of countries and companies and is fundamental to job creation and economic growth. Table 1 shows the ranking of logistics systems' efficiency among 160 countries according to the composite LPI index, in which the leaders of the ranking correspond to the highest values of this indicator, and the countries occupying the last positions - the lowest ones. The middle positions in the ranking are occupied by countries with averages from 0 to 100. The analysis of the data in Table 1 shows that high logistics performance is accompanied by high income of the country's economy. Thus, the leader in efficient logistics according to the LPI composite index rating as of 2021 is Germany. The middle positions in the ranking belong to transition economies - Armenia and Russia. The last positions are taken by developing countries - Burundi, Angola and Afghanistan, respectively.

Table 1 Countries with the highest, moderate, and the lowest logistics 'friendliness' as per 2021

Rank	Country	% from the leader	Customs		Infrastructure		International shipments		Logistics competence		Tracking & tracing		Timeliness	
			Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score
Top performers														
1	Germany	100	1	4.09	1	4.37	4	3.86	1	4.31	2	4.24	3	4.39
2	Sweden	95.4	2	4.05	3	4.24	2	3.92	10	3.98	17	3.88	7	4.28
3	Belgium	94.9	14	3.66	14	3.98	1	3.99	2	4.13	9	4.05	1	4.41
Moderate performers														
70	Latvia	56.5	49	2.80	49	2.98	81	2.74	81	2.69	77	2.79	113	2.88
75	Russia	54.9	97	2.42	61	2.78	96	2.64	71	2.75	97	2.65	66	3.31
92	Armenia	50.2	81	2.57	86	2.48	95	2.65	97	2.50	113	2.51	111	2.90
Bottom performers														
160	Burundi	33.2	159	1.69	146	1.95	139	2.21	117	2.33	156	2.01	158	2.17
160	Angola	32.6	160	1.57	153	1.86	143	2.20	155	2.00	157	2.00	140	2.59
160	Afghanistan	29.6	158	1.73	158	1.81	152	2.10	158	1.92	159	1.70	153	2.38

Source: Adapted from The World Bank [25].

As shown in Table 1, developing countries retain the ability to move goods and link companies and consumers to international markets, but the logistics system requires comprehensive changes in a number of policy aspects: infrastructure, trade facilitation, and improved services. The current situation in countries with economies in transition also requires increasing the current level of available resources and intensifying interaction and cooperation between countries, as evidenced by the low efficiency of customs and border controls; traceability and the formation of international transport corridors. For a detailed study of the logistical constraints identified in Table 1, it is advisable to conduct an internal efficiency analysis of logistics LPI in the context of the regulatory framework of Russia, as an example of a country in transition, which demonstrates the positive dynamics in transport logistics, and the international leader in the composite LPI index - Germany (Table 2). Assessment of the internal logistics environment is based on four main criteria that determine the effectiveness of logistics at the macro level of the country: border procedures; infrastructure; services; process efficiency and time; implementation and development, which increases the reliability of the supply chain.

As the analysis of Table 2 shows, Germany is a country with a high quality of transport infrastructure, service and regulatory transparency in the field of transport communications. In Russia, the basic criteria of the internal logistics environment are at a low level, resulting in a gap in the form of low organisation of logistics chains from the position of state regulation and unpreparedness for the mandatory digitalisation of public institutions, which is a catalyst in logistics. This management style leads to non-transparency and inefficiency in the practice of regulatory support.

The strategic goals of the government policy in the field of transportation are defined in the Transport Development Strategy until 2030 [3], using the normative approach. This allowed identifying the fundamental factors affecting the national economy and determining the fundamental changes required to prioritise the transport policy at the national level in the context of global competition (Figure 1).

The SLS (Figure 1) provides a step-by-step statement of issues on logistics management at the macro level, which is recommended to implement to reduce the logistical constraints through improving the state transport law in accordance with the stated objectives of the strategy. The presentation of changes in the SLS is divided into two stages, which reflect the consensus on the implementation of the national transport strategy and the accumulated experience of developed countries. The first stage focuses on the factors affecting the national economy. The second phase focuses on the necessary practical implementations to improve competitiveness in the global marketplace. Taken together, the two stages rely on the achievement of goals in terms of social, economic and transport results:

1) expansion of transport service in the context of global competition;
2) social inclusion in relation to transportation services;
3) environmental safety of transport infrastructure;
4) creation of a unified base of the transportation system;
5) improving the safety of the transportation system by attracting a workforce with technological skills and analytical abilities;
6) availability of digital technologies and services in the transport service.

Table 2 International LPI data as per 2021: Russia vs Germany

Basic criteria of logistics performance	Russia	Germany
Level of Fees and Charges	Percent of respondents answering high/very high	
- Port charges	25%	47%
- Airport charges	33%	58%
- Road transport rates	25%	27%
- Rail transport rates	50%	25%
- Warehousing/transloading charges	0%	41%
- Agent fees	25%	10%
Quality of Infrastructure	Percent of respondents answering low/very low	
- Ports	50%	0%
- Airports	50%	0%
- Roads	75%	14%
- Rail	50%	23%
- Warehousing/transloading facilities	0%	0%
- Telecommunications and IT	50%	14%
Competence and Quality of Services	Percent of respondents answering high/very high	
- Road	0%	95%
- Rail	0%	62%
- Air transport	25%	95%
- Maritime transport	50%	95%
- Warehousing/transloading and distribution	25%	100%
- Freight forwarders	50%	80%
- Customs agencies	25%	79%
- Quality/standards inspection agencies	50%	63%
- Customs brokers	50%	75%
- Trade and transport associations	25%	63%
- Consignees or shippers	25%	53%
Efficiency of Processes	Percent of respondents answering high/very high	
- Clearance and delivery of imports/exports	25 - 50%	90 - 95%
- Transparency of customs clearance	50%	89%
- Transparency of other border agencies	50%	86%
- Provision of adequate and timely information on regulatory changes	25%	90%
- Expedited customs clearance for traders with high compliance levels	25%	80%
Sources of Major Delays	Percent of respondents answering often or nearly always	
- Pre-shipment inspection	0%	5%
- Solicitation of informal payments	25%	5%
Changes in the Logistics Environment Since 2015	Percent of respondents answering improved or much improved	
- Customs clearance procedures	50%	56%
- Trade and transport infrastructure	25%	45%
- Telecommunications and IT	75%	50%
- Private logistics services	75%	70%
- Regulation related to logistics	50%	20%
- Solicitation of informal payments	25%	18%
Developments since 2015	Percent of respondents indicating much increased or increased	
- Demand for traditional freight forwarding	25%	15%
- Cybersecurity threats in logistics	0%	11%
- Firms preparedness for cyber threats	0%	5%

Source: Adopted from World Bank [25].

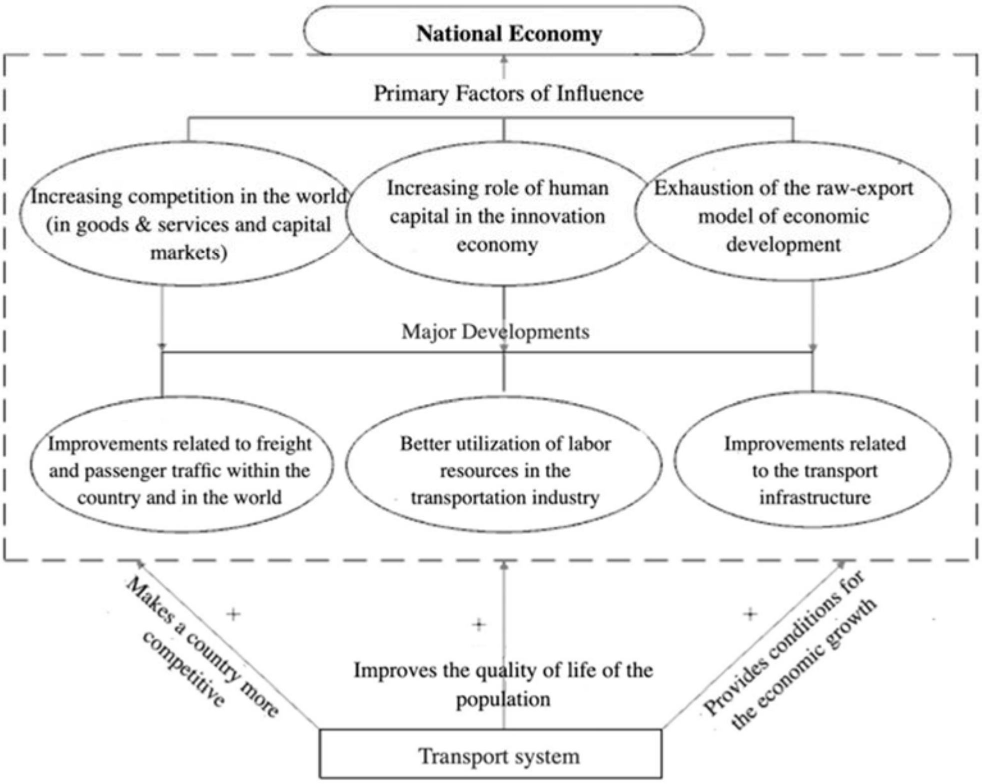

Figure 1 The structural-logistics schematic representation of the Russia's transport system development in the context of globalisation
Source: Developed using data from the Ministry of Transport of the Russian Federation [3].

The results obtained in this study show the high unevenness in the transport logistics system between developed and developing countries and the significant potential for transition economies. Analysis of the monitoring data found that high LPI composite index scores correspond to a high income level of the economy, which is consistent with the results of Hofman [26]. At the same time, increased economic integration of transition countries that have opportunities for development (Armenia, Russia) will help to overcome the logistical limitations in their development. Dunaev et al. [27] argue that logistics is a technology of supply chain management, integration, cooperation and coordination of networking of business processes, which plays a key role in bridging the gap in transport communications and organisation of value chains in the context of globalisation trends. Consequently, supply chain disruptions can have serious consequences for both government agencies and private companies [28]. Significant delays in delivery can lead to more problems in the public sector as well. They also distort the country's image on the international arena. National policy should assess the potential impacts of negative events on its transport system, economy, society and resources. It should improve a supply chain approach that includes a mix of regulatory, information and physical infrastructure actions, as well as coordination between jurisdictional boundaries and between transport service providers, and their clients [29]. Thus, the problems of legal regulation in the field of freight transportation within a supply chain depend mainly on how much the rules of law meet the realities of economic activity. Affecting the logistics environment with policy instruments will give a positive feedback if the impact meets modern market relations and aims at the regulation of economic ties [30]. A comparative analysis of the structure of internal logistics environment in Russia, which occupies an average position in the international LPI rating and has the potential to develop and Germany, which is currently the benchmark in the industry, showed the advantages of effective organisation of transport logistics, which is significant for the improvement of the transport system in Russia. Issues of transport logistics optimisation have been studied by Sidorenko and Makhina [31], Burov [32]. Researchers revealed the lack of consistency when it comes to ensuring security in transport communications, and proposed to optimise transport communication in the direction of coherence of different transport modes using mandatory digitalisation and simplification of regulatory and customs procedures, which is consistent with the results of this study. Currently, Russia has unresolved problems concerning customs and border management clearance. Customs use traditional approaches to process organisation, which do not meet the rapidly changing globalised reality. Boyko [33] examined the experience of foreign countries and found that customs services could be efficient with informatisation. The author suggests establishing a service customs system where goods are tacked at all stages of a supply chain. Dmitriev [34] investigated the regulatory framework for freight transportation in a digital economy. He concluded that transport infrastructure had become more digitalised. Consequently, the legal regulation became more transparent. The review of the strategic development priorities in the transportation sector of Russia, using the normative approach, made it possible to group the national transport policy priorities of Russia in the context of global competition [3]. The European Commission also emphasises the importance of strategic objectives. The main aim of those is to develop the transport sector. Kolik et al. [35] argue that the strategic infrastructure package should include: national policy frameworks, commercial business models, strategic planning, assured financing, sufficient gateway capacity, international and domestic communications, and a green economy. Serieva [36] notes that in the context of global competition, the development of the transport system in all sectors of the economy is far ahead of state regulation. Within this framework, the researcher found that no matter that transport activities are regulated by laws and by-laws, in Russia, there is no unified framework for the legal regulation of supply chains as a set of subjects, products and transportation-related economic activities [37,38]. Regarding the problem of practice, this article focuses on the implementation and use of the experience gained in the logistics system of developed countries, in particular the leader in international logistics (Germany), which is reflected through SLS.

4 Conclusions

The review of legal regulation in the field of freight transportation within a supply chain unveiled the following problems of transport communication: non-transparent regulation within the customs system, the low quality of services, and reluctance to expand digitalisation. These weaknesses slow down the economic development of Russia and lowers its level of competitiveness. The World Bank [39] ranks Russia 75th among 160 countries in term of logistics performance. The country has three domains that need attention: customs and border management clearance, tracking and international shipment. Strict prioritisation is essential to maintain and modernise the existing infrastructure. The study suggests improving the national approach to organising domestic logistics. It should be done in accordance with the strategic goals established in the Transport Development Strategy of the Russian Federation until 2030 taking into account the global experience. In this regard, it is necessary to address the shortcomings of legal regulations as they may slow down market development. This study is can be considered timely and relevant as transport communications and system sustainability are of high priority in the national transport policy of the Russian Federation.

Results can be applied by managers in the public and private sector working in the field of transport logistics, as the study offers a practical tool to improve transport system efficiency based on the accumulated best practices of leaders in this field.

The further work is recommended to connect with the study of macroeconomic indicators of transport logistics within the national economy from two perspectives: effective supply planning and demand forecasting to correct transport failures in practice.

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THE IMPACT OF LOGISTICS CAPACITIES ON THE LOGISTICS PERFORMANCE OF LSPS: RESULTS OF AN EMPIRICAL STUDY

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Keywords: logistics capacities, customer satisfaction, logistics performance, international trade, logistics skills.

Abstract: This paper has a dual objective, to specify the logistical capacities of Moroccan Logistics Service Providers (LSPs) and to understand the process by which these capacities contribute to the logistical performance of LSPs. Methodologically, we used the qualitative approach based on a sample of sixteen LSP. The results of this research show that the main logistical capacities of Moroccan LSPs are flexibility and innovation, which respectively abound in reactivity/proactivity and technological innovation / administrative innovation. Similarly, "customer response" appears to be a purpose that overlaps with logistics performance. Thus, this variable mediates between flexibility and logistics performance. This study also tries to analyse the emergence of new moderating variables, particularly "logistics skills," which strengthen the relationship between innovation and customer response, and "communication with employees" as a support for maintaining performance logistics.

1 Introduction

Over the past decade, the actors of the Moroccan logistics community have undergone a strong change in terms of the services offered to compete with the demands of the ordering companies. Thus, the use of Logistics Service Providers (LSP) constitutes an important lever of competitiveness. To this end, logistics service providers (LSP) are placed at the center of public guidelines in order to support the actors of the Moroccan logistics community in the development of their service offer and to provide them with the skills and capacities to serve supply chains better and meet customer requirements in terms of flexibility and innovation.

Consequently, the logistics market has undergone considerable development marked not only by the multiplication of logistics operators but also by the variety of the range of offerings ranging from basic transport services to full management and management of the customer's logistics and supply chain function. However, the pace of development of the logistics service sector in Morocco is considered low and well characterised by its youth, as evidenced by the timid warehousing outsourcing rate of 14%, which leaves many challenges to be overcome by companies. Moroccan logistics operators in order to capture more business and increase their performance.

In this context, determining the logistical capacities of Moroccan LSPs and analysing their contributions to the performance of LSPs are at the center of the concerns of the academic community in order to support them in the development of their service offer and to equip them with skills and capabilities that enable them to serve supply chains better and meet customer demands in terms of flexibility and innovation. In this perspective, the following problem arises: how are logistics capacities reflected on the performance of LSPs? The breakdown of our problem allows us to identify two research questions to which we will seek to provide answers in this paper: What are the logistical capacities of the field of activity of Moroccan LSPs? How would these capacities have contributed to strengthening logistics performance?

2 Literature review

The analysis of the literature aims to identify and analyse the importance that researchers attach to logistics capabilities and the impact that these have on the logistics performance of companies in general and LSPs in particular. Concerning the impact of logistics capacities on the logistics performance of LSPs, we were able to identify 3 levels relating to state of the art: innovation and logistics performance, flexibility and logistics performance, customer response and logistics performance.

2.1 Innovation and logistics performance

Logistics innovation capability can be defined as a new and useful idea, procedure or practice in logistics practices that differ from the current practices of the company and competing companies. This capability is of crucial importance for the success and survival of LSPs in a dynamic environment [1,2]. In this sense, Wagner [3] point out that LSPs can take advantage and opportunities that arise in the market, generating innovations in logistics. It concerns the practice of renovating business processes as well as the creation of new markets to meet untapped needs.

The literature highlights two dimensions of innovation capacity: technological innovation and administrative innovation. Technological innovation is the ability to adopt the technology by introducing technological changes related to the nature of the company's main activity to offer a new service [4,5]. It is also designed by d other researchers as a managerial innovation [6]. On the other hand, while administrative innovation includes the organisational structure and administrative processes, it is indirectly linked to the basic activities of the organisation and more directly to its management [7].

The capacity for innovation impacts the logistics service of the LSPs by strengthening the long-term relationships with the customers, which makes it possible to make the customer loyal, which in turn generates the acquisition of the advantage of competitiveness and maintaining logistics performance [8]. Moreover, the capacity for innovation, which aims to research and integrate customer expectations into the service provided, is the first step towards logistics performance for LSPs [9].

Indeed, the capacity for innovation is considered by many researchers to be a decisive determinant of the logistics performance of LSPs [2,10,11]. Similarly, Grawe and Kandampully [12,13] asserted that the capacity for innovation, which relies on the use of technology and other resources, fully contributes to achieving logistics performance.

2.2 Flexibility and logistics performance

Flexibility is defined as the capacity of a logistics system to adapt in a proactive and reactive way its configuration, the objective of which is to eliminate the market fluctuations [14]; it corresponds to the ability of LSP to respond effectively to market fluctuations and customer requirements [15]. Logistical flexibility is intended by Judge [16] as the capacity for organisational change, which conditions the effectiveness with regard to the implementation of a permanent change.

Indeed, in a supply-chain context, flexibility has two dimensions, reactive and proactive [17]. Responsiveness consists of responding to the uncertainties generated by the supply chain, the notion of uncertainty is linked to the lack of environmental information, making it difficult to predict the impact of decision-making on the organisation [18].

Flexibility significantly impacts logistics performance as it supports the logistics performance of LSPs in terms of customer response, efficiency and quality of service [5]. Moreover, it is often retained in the literature as being a fundamental variable for maintaining competitive advantage [19]; it thus serves to improve the competitiveness of the LSPs.

In the same vein, Anand [20] claims that logistics service flexibility is considered to be a predictor for logistics performance. Moreover, LSPs that hold the logistics flexibility capability can gain a competitive advantage and are often able to achieve logistics performance [21,22]. Logistics flexibility is, therefore, a determining variable for the achievement of logistics performance for LSPs. Especially in a dynamic environment, it depends on the speed of response to customer requests at the best prices [23-25].

2.3 Customer response and logistics performance

In the service sector, the customer is the central element, and his satisfaction determines the success of LSP [26]. Satisfaction is linked to very particular attention, such as an expectation, a product/service or an experience. LSPs that develop customer responsiveness are better prepared to meet the diverse needs of customers, offering them varied services accordingly. Therefore, to hold a competitive advantage, the development of customer response capacity is achieved by increasing the time, quality, and price of the services offered [27,28].

Customer satisfaction capability is positively related to performance. LSPs that maintain this capability are often able to maintain the existing customer base and attract new customers, so they will be able to meet the particular needs of the market [29]. According to Lai [30], LSPs with better service capability are better established to cope with customers' diverse service needs and achieve better service performance. The ability to satisfy the customer is, therefore, the ability of LSPs to create and allocate resources to satisfy the logistics needs of their customers and consequently ensure better logistics performance.

In the same sense, Zhao [29] concludes that the ability to satisfy the customer is significantly linked to performance. These conclusions are supported by Ching-Chiao Yang [31], stating that meeting customer expectations in the service sector positively impact logistics performance and encourages customer loyalty.

In this sense, we can synthesise that several authors have mentioned the problem of evaluating the contribution of logistics capacities to logistics performance. Logistics capabilities are essential for achieving logistics performance and creating added value for LSP customers. Admittedly, research work confirms that logistical capacities, in this case, flexibility, innovation and customer response, contribute to the performance of LSPs, only the modes of influence that differ from one researcher to another.

However, the interest of companies for this issue and the need to deepen it still remain valid, which leads us to identify these capacities empirically and evaluate their impact in the context of Moroccan LSPs.

3 Methodology and sampling

The research methodology used is purely related to the object of study. While the size of the sample, the procedures for processing analysing the data, and the device the researcher should use are intended to ensure the quality of his results.

3.1 Methodological approach and data processing techniques

We adopted a qualitative study by induction approach and positioning in an interpretive paradigm. It is about the determination of the "how" relationship between logistics capacity and performance of LSP.

As for the data collection method, we used the semi-structured interview, which constitutes a privileged instrument in qualitative research since it allows obtaining a good quality of information. Our research questions guide the data analysis. However, although the research objectives initially influence the analysis, the results come directly from the analysis of the raw data and not from "desired answers"[32].

The data collected by our case studies are thus coded and categorised "manually", making a clean sweep of any prejudices. We thus proceeded successively to an initial coding, then to multiple coding and finally to a thematic coding [33]. The subjects identified in these studies allowed us to return to theory and literature review. This back and forth between the field and the theory allowed us to generate proposals and to conceptualise our conceptual model.

3.2 Sampling

Several sampling techniques constituting widely varying sample sizes are used in the qualitative study. Thus, we refer to the guidelines of Gumucio [34,35], according to which two criteria must be highlighted to justify the sample: the size of the sample and the context of the study.

The sample size corresponds to a gradual construction to know when the researcher should stop [36]. The number of cases studied will stop when there is saturation. This semantic saturation is reached when the new cases only repeat what has been said by the others [37]. Thus, we were satisfied with a sample of 16 cases allowing us to meet this saturation criterion.

The choice of study cases was made in a nonarbitrary and impartial manner to ensure that the selected study cases responded to several criteria. Our convenience sample is for LSPs in the logistics services industry operating nationally and internationally to procure various information. In addition, the use of actors of different qualities is considered, on the one hand, as sources of information to understand the logic and sectoral trend of the LSP studied. Twenty-two LSPs, of which we selected only sixteen given the saturation criterion, agreed to participate in the survey by expressing their interest in sharing their experiences with us. We have assigned codes to the different analysis units to guarantee the anonymity of the interviewed actors.

Table 1 Characteristics of the LSP sampled and of the interviewees

Code	**Activity area**	***Creation***	***Quality of interviewees***	***Experience***
LSP1	Logistics service provision	2007	Park manager	7 years
LSP2	Logistics service provision	1937	Tryears port manager	11 years
LSP3	Logistics service provision	1997	Tryears it import/export	5 years
LSP4	Logistics service provision	2011	Tryears port manager	6 years
LSP5	Logistics service provision	2012	Tryears port coordinator	4 years
LSP6	Logistics service provision	1982	Operation manager	9 years
LSP7	Logistics service provision	2009	Operations manager	2 years
LSP8	Logistics service provision	2007	Tryears it and tryears port agent	7 years
LSP9	Logistics service provision	1996	Tangier agency manager	5 years
LSP10	Logistics service provision	2011	Warehouse manager	5 years
LSP11	Logistics service provision	2009	Internal freight forwarder	2 years
LSP12	Logistics service provision	1994	International tryears port manager	9 years
LSP13	Logistics service provision	1999	Tryears port manager	2 years
LSP14	Logistics service provision	2001	Customs declarant	9 years
LSP15	Logistics service provision	1980	Tangier warehouse manager	4 years
LSP16	Logistics service provision	2003	Planner	8 years

4 Data processing and analysis

4.1 Thematic coding

We conducted triple coding, initial coding, grouping, and thematic coding. The thematic codification, through which we affiliate a synthetic concept to each grouping [33], represents the results of our coding. The following table lists a summary of our triple coding.

According to this grid, the grouping set is granted thematic codes representing the results of our coding. There are four-axis: "Flexibility", "Innovation", "Customer response" and "Logistics performance".

Indeed, flexibility refers to proactivity and reactivity; Innovation combines administrative innovation and technological innovation. Customer Response includes three categories such as service quality, service time, service price, Logistics Performance. On the other side, by identifying three-axis categories, namely differentiation, effectiveness and efficiency.

Table 2 Summary of Thematic coding

Verbatim	Codes	Grouping	Thematic coding
You don't just adapt to environmental changes these days, but sometimes you have to create that change.	Proactivity	Adaptation	**Flexibility**
Sometimes customers change their delivery plan, and our business has to adapt in return.	Reactivity		
We adopt the capacity for innovation to offer and benefit from certain technologies' gains.	Technological innovation	Creativity	**Innovation**
Reconfigure operations so that they are adapted to the new criteria.	Administrative innovation		
The quality of delivery is also very important.	Quality of service	Customer satisfaction	**Customer response**
The delivery time is a fundamental factor in responding to the customer.	Service time		
Price has always been an element of performance for companies.	Service price		
This differentiation allows us to achieve and capture a competitive advantage in the market.	Differentiation	Performance	**Logistics performance**
Achieve our logistics objectives, and be efficient.	Efficacity		
It is with efficiency, and this is the result of our service.	Efficiency		

4.2 *Inductive*

After the data processing and the coding of the verbatim of the studied cases, we present the inductive ones taken from LSP. Inductive information will allow us to bring out other variables and identify the relationships between the different axes.

Table 3 Inductive lessons

Codes	Emerging relations	Examples	Observations
Flexibility	Reactivity / Customer response	Our company's behaviour may turn out to be in some reactive cases and other proactive cases. Flexibility consists of reconfiguring the logistics function to meet market demands	The two dimensions of the "flexibility" capacity are intended to meet a diversified demand from customers. Therefore, customer response is a goal of LSP insofar as logistics capacities impact customer satisfaction. Customer response is a mediating variable between flexibility and logistics performance.
	Proactivity / Customer response		
Innovation	Administrative innovation / Customer response	Also, the information system that we are putting in place helps us comply with customer instructions regarding delivery times and delivery quality and, therefore, helps us improve our performance.	The two dimensions of innovation impact customer response, especially in terms of price, time and quality of service. Customer response is, therefore, a mediating variable between innovation and performance.
	Technological innovation / Customer response	We are seeing the effects of technology that allows us to reduce the costs of services and offer them to the market at a competitive price. Which positively influences our logistics performance	
Logistics skills	Logistics skills / Innovation / Customer response	The use of technology provides the user has the necessary skill, reduces costs and helps achieve goals (...) Technological skill is necessary so that the technology can be used for logistics performance	Logistics skills facilitate the handling of innovative tools for customer satisfaction. Therefore, logistics skills is a moderating variable that strengthens the relationship between innovation" and "customer response.

Many additional lessons were identified, enabled by the inductive approach adopted in this research work. Indeed, in several cases, "customer response" appears as a purpose that overlaps with logistics performance. Thus, this axe is a mediating variable between flexibility and logistics performance.

Analysis of what the interviewees said allowed us to deviate from the role of some variables and identify other variables that have not yet been highlighted in the literature. Thus, the inductive approach of LSPs can be summarised as follows:

Regarding the change in the role of some variables, the customer response is no longer a logistical capacity in our study context. It is rather a mediating variable located between, on the one side, flexibility and logistical performance and, on the other side, between innovation and logistics performance.

For the new emerging variables, it is linked to "logistics skills" which has a moderating role between innovation and customer response and, and to "communication with employees as a support for maintaining logistics performance which is, here, a moderating variable that reinforces the relationship between logistics performance and the other variables, the "customer response".

5 Discussion of the results

5.1 *Logistics capacities*

The logistical capacities of our sample are three in number. Again, it is about flexibility, innovation and customer response.

Flexibility: Flexibility is a capacity that the company has to adapt to changes in the competitive environment and also to customer requirements in terms of delivery times. Through this ability, the company acts, as the case may be, reactivated or proactively in the face of any change. In this framework, the leader of an LSP assures us that "The behaviour of company can prove to be positive in some reactive cases and negative in other proactive cases (...). Flexibility consists of reconfiguring the logistics function to meet the market's demands" (LSP1).

According to the literature, flexibility is defined as the ability of a logistics system to proactively and reactively adapt its configuration, the objective of which is to cope with market fluctuations [14-37]. It corresponds to LSP's ability to respond effectively to market fluctuations and customer demands [15].

Consequently, the way they are perceived, the two dimensions of flexibility, in this case, responsiveness and proactivity, and their purposes among the LSPs in our sample, corroborate the definitions and objectives noted in the literature.

Innovation: Innovation among the LSPs in our sample revolves around two poles, the administrative pole and the technological pole. According to one respondent, "The innovation concerns the innovation of the service offered, the innovation of the logistics strategy, even innovation in terms of logistics means (…) company has invested many years in technological solutions, and especially RFID for the management of the inputs and outputs of the "LSP3" warehouse (LSP3). Through these two dimensions, in this case, administrative innovation and technological innovation, innovation concerns the whole company; this is confirmed by a leader who states that "these innovations affect almost all departments of the company. The materials and procedures are good examples" (LSP4).

The two dimensions of innovation are highlighted by returning to the literature, given their importance. For technological innovation, Daft [4] considers it to be the introduction of technological changes linked to the nature of the firm's main activity. Therefore, according to Yang and [5-38], it is the ability to adopt a technology to offer a new service. As for administrative innovation, it encompasses the organisational structure and administrative processes. It is indirectly linked to the basic activities of the organisation and more directly linked to its management [7-39]; this is also called managerial innovation [6].

Thus, LSPs have opted for changes in the way managers' work is done and have introduced technological changes to adapt to the sector's dynamism.

Customer response: Considered an important capability in the context of Moroccan LSPs, customer response is a company's ability to meet customer requirements in terms of three attributes, quality, price and lead time. An interviewee announces to us this prospect "The response to the customer is quite an important logistical capacity. The purpose of all LSPs is to respond to the customer, in terms of price, quality and also deadlines. "(LSP3). Customer response is assessed in terms of customer expectations. The response to their expectations confirms the level of satisfaction. This is why, according to the interviewees' answers, the customer response refers to their satisfaction.

The mobilisation of a set of parameters to satisfy customers, the parameters are thus antecedents to the customer response, this corroborates the words of another LSP who affirms that "we take into account all the parameters to meet the customer whether in terms of quality of service, time or even price." (LSP5). Therefore, customer response, although it is considered a logistical capacity, other parameters are crucial to achieving it; this is the reason why it is considered a finality in our sample.

Regarding the literature, by focusing on the service sector, the customer represents the central element and his satisfaction conditions the success of LSP [26]. So customer satisfaction is an answer, and it is always linked to very specific attention, such as an expectation of a product/service. This response occurs after service use [39].

Therefore, the customer response even refers to customer satisfaction in terms of price, quality and time. It metamorphoses our sample and corroborates the theoretical contributions of the concept.

5.2 The contribution of logistics capacities in Moroccan LSP

5.2.1 Flexibility and customer response

Flexibility largely affects customer satisfaction, in the context of Moroccan LSPs, in terms of customer response. Thus, to respond to unforeseen requests, the urgency requiring a rapid reaction, flexibility allows the company to respond quickly, which allows it to avoid the delay, although the latter could arise from people outside the company, the customer or the sender. Having said that, according to one executive, "We get very special requests from our clients, but we try to meet them by dealing with different clients with specific needs. "(LSP7)

Through its flexibility, the LSPs demonstrate the ability to manage the emergency situation often encountered. This results in customer satisfaction and therefore demonstrates the improvement of the offer to customer response. This corroborates the words of another interviewee who states: "if we can adapt quickly, this will also allow us to meet the needs of customers in an efficient manner" (LSP3)

Flexibility stimulates customer response in terms of delivery time, price and quality of service, which refers to the testimony of the manager who sees that "This adaptation consists in making the service capable of meeting the specific need of the customer" (LSP4)

Regarding the literature, Wright [40] argues that flexibility is dependent on LSP's ability to reorganise its resources and activities to meet customer demand quickly. Hence the following first proposition:

P1: LSP flexibility has a positive and significant impact on customer response.

5.2.2 Innovation, customer response and the moderating role of logistics skills

As highlighted by Moroccan LSPs, technological innovation and administrative innovation are decisive capacities for the expectation of an objective that is transforming the response of customers. Customer response, which is dictated by the establishment of innovative capacities that are mobilised for previously defined objectives, appears to be a purpose that overlaps with logistics performance. An interviewee said this framework: "We do not miss the opportunity to implement such an innovative procedure that can promote and improve customer service and meet their expectations. For example, innovation in terms of work procedure, innovation in terms of control procedure" (LSP1). Therefore, innovation is considered an external element to the extent that it consists of better serving the customer (principal).

The analysis of the comments of the respondents, taken from our sample, allowed us to deviate from the role of "customer response" and to identify other variables that have not, so far, been highlighted in the literature.

Regarding the change in the role of the variable "customer response", although some authors, in this case, have considered it as a capacity[29,30], customer response is a goal of other logistical capacities (flexibility and innovation) in our context.

For the new emerging variables, this is "logistics competence", a moderating variable that strengthens the relationship between innovation and "customer response" in the case of our study context. We bring this perspective to life in the words of one respondent who said that "if you don't have the capable and competent people to use this technology, it will be a failed investment or rather a divestment" (LSP16).

Logistics skills facilitate the handling of innovative tools for customer satisfaction. This corroborates the statements of the interviewees who state that "The use of technology provided that the user has the necessary skill, reduces burdens and help achieve objectives (…) Technological competence is necessary for the technology to be used to logistics performance" (LSP13).

Moreover, the effects on customer satisfaction are greater if these so-called skills are well mastered. "I think it will be wide if our staff and especially the technicians know how to handle it quickly" (LSP14). Moreover, for the proper handling of technology, training must be provided on the best method, which is confirmed in case 16: "to use it and sometimes you have to write for each user the detailed steps to follow to carry out these activities". (LSP16)

According to the literature, the capacity for innovation is of critical importance to the survival of LSP in a dynamic environment [1]. By treating its contributions, highlights the customer's place as a finality[9], the customer is the central element and his satisfaction conditions the success of LSP in the service sector. To meet its expectations, Yang [5] has shown that logistics innovation is positively linked to operational efficiency and quality of operational service. Grawe [12] argues that innovation in logistics relies on technology and other related resources to meet customer demands.

As a result of the analysis of the spreading remarks and the theoretical foundations, the capacity for logistics innovation reflects the ability of LSPs to develop and offer new logistics solutions to meet the needs and wishes of customers in an environment of more in addition to dynamic, logistics skills play a moderating role in this relationship. Hence our second following proposition:

P2: Logistics innovation has a positive impact on customer response, logistics skills play a moderating role during this relationship.

5.2.3 Customer response, logistics performance and the moderating role of customer communication

Customer response inspires confidence and enables long-term customer engagement because, according to one leader, "Responding effectively to special requests increases the confidence of our customers and solicits us for all their operations and most importantly. make a long-term commitment with us" (LSP1). As a result, when trust is built, and customer engagement is sustained over the long term, LSPs achieve a goal of total logistics service performance. This corroborates the words of another leader who says that "when customers trust us and engage with us, we are very likely to meet our goals of performing and growing afterwards. (LSP13).

Thus, achieving logistics performance is a linear process that goes from customer response, trust and commitment, and consequently, the service's overall performance. This performance is reflected in the return of satisfaction in terms of customer engagement and the building of strong customer trust. What is approved by one respondent: "Logistics performance is measured by the degree of customer satisfaction and by the degree of achievement of the objectives of each department" (LSP15).

The literature has highlighted the expected return of the customer in terms of his satisfaction. In the service sector, customer satisfaction is recognised as a decisive factor in maintaining and consolidating long-term business relationships [29]. The customer is thus the central element, and his satisfaction conditions the success and performance of LSP [26]. Therefore, customer satisfaction is achieved when logistics service performance meets or exceeds customer expectations [30]. Ching-Chiao [31] support this idea by arguing that one of the most important elements is the service sector and the maintenance and development of the long term relationship with the customer.

The theoretical foundations which corroborate the elements drawn from the respondents' comments make it possible to identify the contributions of the customer response on logistics performance. In this perspective, we find that customer response impacts logistics performance.

However, maintaining performance requires the maintenance of communication to ensure any volatility related to the effectiveness of the service to the customer. According to one interviewee, "The fact that there is an exchange of information with customers that we can know what they need and respond in return, this is how we can achieve performance" (LSP15). This observation is also confirmed by other respondents who tell us that "it takes information for it to contribute to our performance" (LSP16).

Therefore, maintaining communication with customers is decisive in ensuring an overall performance that meets all of their expectations. It even ensures the sustainability of the relationship according to the perception of the leader of the LSP15 who sees that "Maintain a communication with the customer service customers to try to work with them as long as possible" (LSP15). Thus, customer communication plays a moderating role by strengthening the relationship between customer response and logistics performance.

The study demonstrates the existence of a clear two-way relationship between customer response and the logistics performance of Moroccan LSPs. Furthermore, customer communication helps maintain this relationship. Therefore and after this discussion, we put forward the following proposition:

P3: There is a significant and positive relationship between customer response and logistics performance, customer communication has a moderating role during this relationship.

By way of conclusion and conjugation of our proposals, we put forward our following conceptual model:

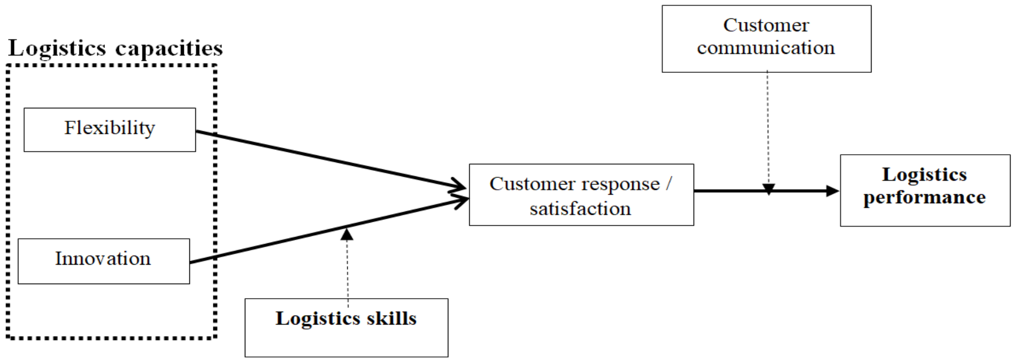

Figure 1 Conceptual model of research

6 Conclusion, limits and perspectives of the research

The purpose of this research is to understand the phenomenon, or even look for the "How", as mentioned in our problem, of the contribution of LSP's logistics capacities to logistics performance. This requires an in-depth qualitative approach.

The results of this research show that the main logistical capacities of Moroccan LSPs are flexibility and innovation, which respectively abound in reactivity/proactivity and technological innovation/administrative innovation. Similarly, "customer response" appears to be a purpose that overlaps with logistics performance. Thus, this variable mediates between flexibility and logistics performance.

This study also highlights the emergence of new moderating variables; on the one side, "logistics skills" strengthen the relationship between innovation and customer response and, on the other side, "communication with employees" as a support for maintaining performance logistics.

By this recourse to a qualitative study, we can accept that the main limitation is relative to the size of the LSP sample which. Moreover, the research to understand this new phenomenon could be put forward as a strong argument for resorting to the qualitative approach. In addition, the second heavy limit on such a research strategy is a bias of subjectivity. Admitting this posture indeed requires thinking about a palliative methodology.

The research is based on a relatively limited number of LBPs. Therefore, although the sixteen cases are chosen, although selected to meet certain basic criteria, the perception of logistics capacities as well as their linkage with logistics performance differ from one company to another. It is, therefore, possible that the selected LSPs exhibit some biases.

Given the framework of the results of this work, it is essential to identify the way for future research which would apprehend the contribution of the logistics capacities of LSP with regard to the theoretical models relating to different contexts. It, therefore, seems essential to broaden the context of the process beyond the multiple case studies. The objective would therefore be generalisation allowing a real gain in objectivity.

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DEVELOPMENT OF A NEW NUMERICAL MODEL OF DYNAMIC HARMONIC REGRESSION FOR THE FORECAST OF SELLING FUEL PRICE IN THE MOROCCAN PETROLEUM SECTOR

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Keywords: liberalization, forecast, time series model, dynamic harmonic regression, decision making.
Abstract: The liberalization of the petroleum sector in Morocco has a significant effect for petroleum product distributors. Since the beginning of December 2015, fuel prices are freely determined. This event presents many constraints affecting the balance of the sector plus the competition among its economic players. As all fuel products are imported, we will be interested in the evolution by making forecasts of the price of fuels in the Moroccan market. In this context, our paper aims mainly to study the time series of diesel and gasoline in order to provide precise forecasts to the company and to respect the permissible error margin of 3%. To this end, the harmonic dynamic regression model through the proposed process approach yielded excellent forecasting results for the first quarter of 2017 with an average error margin of 1.617%. Compared to ARIMA model, the harmonic dynamic regression proves its strength manifested in the low rate of error. In addition, the assumption that the residuals are a Gaussian white noise has always been verified. The forecasts obtained are very crucial for managers to take good decisions at the strategic level.

1 Introduction

Oil is an important sector given the increasingly competitive nature of the industry today. Large companies and oil suppliers want the most economical and reliable forecasting mechanism to evaluate the market. For this reason fuel price forecasting is one of the most important problems beyond all strategic and planning decisions in any company [1], but difficult in the research areas of the analysis and prediction of because of the uncertain interactive factors that determine the oil market.On the one hand, oil is directly associated with various uncertain market factors, such as supply and demand, competition among suppliers, substitution for other forms of energy, economic development, population growth, and technical development [2]. On the other hand, as crude oil is a dominant resource for energy security, the oil market is highly sensitive to various uncertain external factors, such as political instability, war and conflict [3,4]. Since 01 December 2015, fuel prices are freely fixed. This event presents a lot of constraints impacting the balance of the sector and the competition among its economic actors. The lack of support measures by the state makes it vulnerable. With the cessation of the activity of the only Moroccan refinery, distributors must, from their part, build up large stocks. As all fuel products are imported, we will be interested in the evolution by making forecasts of the price of fuels on the Moroccan market. In order to remain competitive on the market, distributors must be able to source fuel at the optimal price while maintaining a significant profit margin. In order to achieve their objectives, oil companies must rely on very specific forecast mechanisms.The overall mechanism by which the price of oil affects most countries or national economic factors are generally well understood, and thus the forecast of the price of oil has been perceived as an important research topic.One of the most commonly used approaches for oil price prediction is the statistical time series method [5,6], characterizing the price of oil as a time trend, a seasonal factor, a cyclical element and a term of error. Many techniques are available to break a series of oil prices in these components.They include the Akarca and Andrianacos model medium autoregressive movement (ARIMA) [7], Lanza et al.'S (ECM) error correction model [8], and the vectorial regression of Mirmirani and Li (VAR) model [9].Other types of approaches assume that stochastic quantification, the relationship between oil prices and the latent economy are factors that can provide a more relevant prediction than attempting to discover the underlying structure of the series itself.

Our article studies the price forecast of the Moroccan oil market, which is an important area for the determination of future value, from the point of view of oil distribution companies, considering global variables. We will develop a new numerical model of dynamic harmonic regression that aims to determine the price of fuel in the forecasting process.

2 Literature review

Several articles have been published in the literature, aiming at comparing and improving the prediction capabilities of dynamic harmonic regression and ARIMA models more precisely. Church and Curram (1996) [10] have attempted to predict the decline in the growth rate of Consumer spending in the late 1980s using a network of artificial neurons and a model ARIMA. They suggest that neural network models describe decline as well as, but not better, econometric specifications. Finally, they suggest that the selection of the methodology used to make predictions should be based solely on the variables available. Prybutok et al. (2000) [11] develop a neural network model for predicting daily maximum ozone levels and compare with two conventional statistical models, regression and ARIMA Box-Jenkins models. The results show that the neural network is superior to the other two models tested. Gutierrez-Estrada et al. (2004) [12] use linear multiple regression, univariate time series models (ARIMA models), and neural network computations to predict the average daily ammonia concentration in water-recirculating ponds. The results show that the non-linear ANN model approach provides better prediction of ammonia concentration than the multiple linear regression and univariate time series analysis, when the correlation between the data series is weak and when models are forced to predict in a situation for which they have not been specifically calibrated. Ho et al. (2002) [13] present a comparative study of integrated self-regulating movement Box-Jenkins models of medium and two artificial neural networks with a different architecture (multilayer power supply and recurrent network) in the prediction of failures in computer networks. The study showed that the recurrent network architecture significantly outperforms the results produced by the other two methodologies. In many scientific or technical applications, the data is generated in the form of a time series. As a result, time series analysis is one of the main tools for research and development (Cryer 1986, Chatfield 1991) [14-15]. Modelling of univariate and multivariate time series and structural time series methods have been useful for describing and forecasting (Prybutok et al., 2000, Tsitsika et al., 2007) [11,16].

3 Elaboration of the new methodology

In our study, we will develop a new numerical model of dynamic harmonic regression that aims to ameliorate the forecast of the price of fuel in the forecasting process.

In our previous work, El Bahi et al. (2018) [17] demonstrates the utility of ARIMA model in the forecasting field, we found that the ARIMA model (1,1,1) gave accurate forecasts to the price of gasoline near the margin to be met for the first quarter of the current year with an average error margin of 2,855% respecting thus the margin permissible given by the company. However, in this paper, we will present a new model of dynamic harmonic regression through a proposed new process approach.

3.1 Dynamic harmonic regression

We have developed the basics of the new harmonic dynamic regression model, while performing various tests to validate the proposed model. Our study has focused on the price of diesel fuel in Morocco.

The classic model of additive time series with hidden components is shown in (1).

$$\boldsymbol{Y_t = T_t + C_t + S_t + f(u_t) + N_t + e_t\,;\;\; e_t \sim N(0, \sigma^2)} \quad (1)$$

- $\boldsymbol{Y_t}$: the observed time series
- $\boldsymbol{T_t}$: the trend
- C_t : the cyclical component
- $\boldsymbol{S_t}$: the seasonal component
- $\boldsymbol{f}$: the influence of an exogenous vector with variables $\boldsymbol{u_t}$
- $\boldsymbol{N_t}$:stochastic disturbance
- e_t : Gaussian white noise: $\boldsymbol{e_t \sim N(0, \sigma^2)}$[18].

Nevertheless, we worked only with the following model:

$$\boldsymbol{S_t = \sum_{i=1}^{n} A_i cos(\omega_i t + \varphi_i)} \quad (2)$$

$$\boldsymbol{C_t = \sum_{j=1}^{m} B_i cos(\omega_j t + \varphi_j)} \quad (3)$$

The ω_i andω_j are the Fourier frequencies determined from the discrete Fourier transform through a spectral analysis. This study in the frequency and non-temporal domain allows a consequent gain in parameters [19].

It is interesting to separate the cyclical and seasonal components because even if they are written in the same way, the cycles have relatively large periods compared to the observations and are therefore hardly detectable. In our work, we consider the cyclical component equal to zero because the observations relate only to one year (24 observations / fortnight in all). The parameters n and m depend on the number of observations p. We will see later that:

$$\boldsymbol{n = \frac{p}{3} - 1} \quad (4)$$

For the trend, we will see that the regression line can be a good approximation. The most important thing is that we will detail later that everything is calculated at the same time [20]!

In this study, we will work on the prices of diesel fuel for the development of the model. The points cloud and regression line are presented in figure 1.

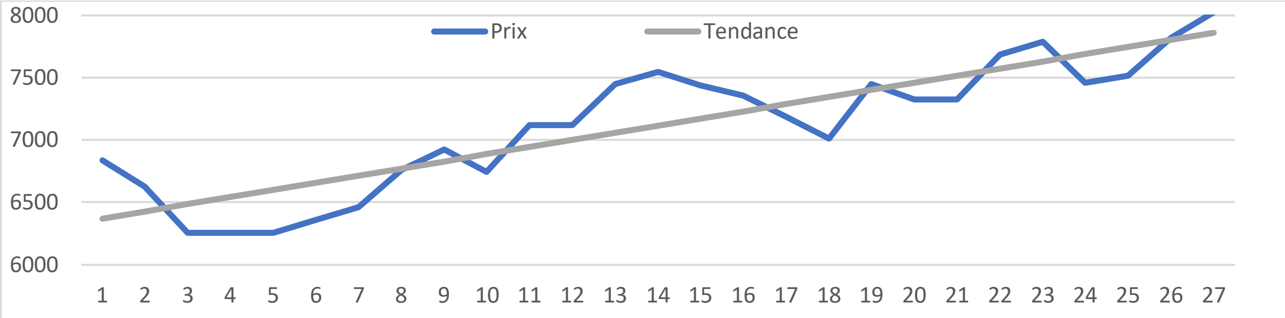

Figure 1 Gas price excluding taxes and trend

3.2 Determination of Fourier frequencies

3.2.1 Methodology

To determine the frequencies of Fourier, we will present two methods: the direct method of the periodogram and the indirect method of Blackman-Tuckey.

Under the assumptions of stationary and ergodic signals, the autocorrelation function and the power spectral density are defined by:

$$r_{xx}(m) = E\{x^*(n)x(n+m)\} = r_{xx}^*(-m) \quad (5)$$

$$S_x(f) = \sum_{m=-\infty}^{+\infty} r_{xx}(m)e^{-2j\pi mf} = \lim_{N\to\infty} E\left\{\frac{1}{N}\left|\sum_{n=0}^{N-1} x(n)e^{-2j\pi nf}\right|^2\right\} \quad (6)$$

It is assumed to have N samples $\{x(n)\}_{n=0}^{N-1}$ of the signal to be analyzed and we, therefore, try to estimate the power spectral density from these data. There are two major classes of non-parametric spectrum estimation, each of which is related to one of the equalities in the spectral density equation.

Periodogram method:

It is a method that uses the signal directly. The spectrum is estimated by (7).

$$\hat{S}_{PER}(f) = \frac{1}{N}\left|\sum_{n=0}^{N-1} x(n)e^{-2j\pi nf}\right|^2 \quad (7)$$

Because of the truncation of the signal, the periodogram is in fact the convolution of the spectrum by a cardinal sinus window. Truncating the signal induces two main phenomena:

- Widening of the main lobe which leads to a decrease of the resolution.
- Appearance of secondary lobes.

The resolution of the periodogram is $1/N$.

To remedy truncation problems, windows are generally used to either reduce the main lobe or attenuate the sidelobes. Also, the periodogram is a biased estimator.

$$E\{\hat{S}_{PER}(f)\} = \int_{-1/2}^{1/2} W_b(f-u)S_x(u)du \quad (8)$$

Where $W_b(f) = \frac{1}{N}\left[\frac{sin(\pi Nf)}{sin(\pi f)}\right]$ is the Fourier transform of the triangular window.

The periodogram is therefore on average the convolution of the true spectrum with the Fourier transform of the triangular window. Nevertheless, when $N \to \infty$, the bias becomes zero. It can also be shown that the variance is virtually independent of N and proportional to the spectrum.

$$var\{\hat{S}_{PER}(f)\} \cong S_x(f)^2 \quad (9)$$

Thus, the periodogram is therefore not a consistent estimator of the Spectral Power Density. In order to reduce the variance of this estimator, an averaged periodogram can be used.

This consists of separating the signal into K slices (of length N / K), calculating the periodogram on each slice and averaging. Due to the average K, the variance is almost divided by K: nevertheless, with the slices being shorter, the resolution decreases.

Indirect method: Blackman-Tuckey:

Another approach is to use the definition of the spectrum from the correlation function. The spectrum is then estimated as in (10).

$$\hat{S}_{BT} = \sum_{m=-M}^{M} \hat{r}_{xx}(m)e^{-2j\pi mf} \quad (10)$$

Where $\hat{r}_{xx}$ is an estimator of the correlation function, given by (11).

$$\hat{r}_{xx} = \frac{1}{N}\sum_{k=0}^{N-m-1} x^*(k)x(k+m) \quad (11)$$

It is a biased estimator. The following estimator is unbiased:

$$\hat{r}_{xx} = \frac{1}{N-m}\sum_{k=0}^{N-m-1} x^*(k)x(k+m) \qquad (12)$$

Blackman-Tuckey suggested taking M of the order of 10% N. The application of a window is possible to reduce the variance on the estimate of the correlation function. Indeed, we have:

$$\hat{S}_{PER} = \sum_{m=-(N-1)}^{N-1} \hat{r}_{xx}(m)e^{-2j\pi mf} \qquad (13)$$

However, the variance over $\hat{r}_{xx}(m)$ increases as m approaches N, this explains why only M correlation points are used. Nevertheless, when M decreases, the bias increases.

=> bias-variance dilemma.

Disadvantages:

- Resolution in 1 / N which implies a certain difficulty in finding two very close lines for short duration signals.
- Difficulty in finding weak signals compared to strong signals.
- Secondary lobes and negative spectra (BT) due to windowing.
- Inconsistent estimate of the PSD.

Advantages

- Very fast and inexpensive computing algorithms (FFT).
- Estimated spectrum proportional to the power.
- Robust behavior on a wide range of signals.

The choice of a window results essentially from the compromise between the width of the main lobe and the height of the secondary lobes. In our study, we will work with Hannig's window because it allows a good compromise.

3.2.2 Spectral analysis

This analysis will allow us to bring out the most significant frequencies (which allow a maximum information gain: signal processing theory).
We will classify the frequencies of the most important (spectral density of the largest to the smallest). Here is the result on Table 1.

Using the SPSS software, we will calculate the other parameters by a non-linear regression. The first idea that comes to mind is to take all Fourier frequencies and build the forecast model for these frequencies. Figure 2 shows the result obtained. The results seem satisfactory, but the strong oscillations push us to study them more closely.

3.3 Oscillation study

To be able to do this study, we have to map the model exactly. But we only have 27 observations. Shannon's theorem states that the sampling frequency (observations) must be greater than or equal to twice the maximum frequency. All calculations done, the theoretical sampling frequency must be greater than 50. We propose to complete our samples to make a polynomial interpolation between each two consecutive points so as to keep a line that passes through two consecutive points and the middle point created. The result obtained is shown in Figure 3. We notice a very strong oscillation among the values which pushes us to consider the application of a filter.

3.4 Static filter proposed

The idea is to build a band pass filter that filters high and low frequencies as shown in figure 4.

New constraints are then added to our model. Recall that the model exclaims as in (14).

Table 1 Fourier frequencies

Frequency	Period	Periodogram	Spectral density
0.2327	27.0000	3705812.5981	294899.1966
0.4654	13.5000	2004167.0706	159486.5480
0.9308	6.7500	307353.1302	24458.3850
1.3963	4.5000	171525.5708	13649.5712
0.6981	9.0000	162633.9992	12942.0024
1.6290	3.8571	159402.0988	12684.8160
1.8617	3.3750	85748.8769	6823.6788
2.3271	2.7000	72878.7657	5799.5079
3.0252	2.0769	62642.4908	4984.9310
1.1636	5.4000	57555.0920	4580.0887
2.7925	2.2500	47251.8233	3760.1806
2.0944	3.0000	26826.4541	2134.7814
2.5598	2.4545	20257.9969	1612.0802
0.0000		0.0000	0.0000

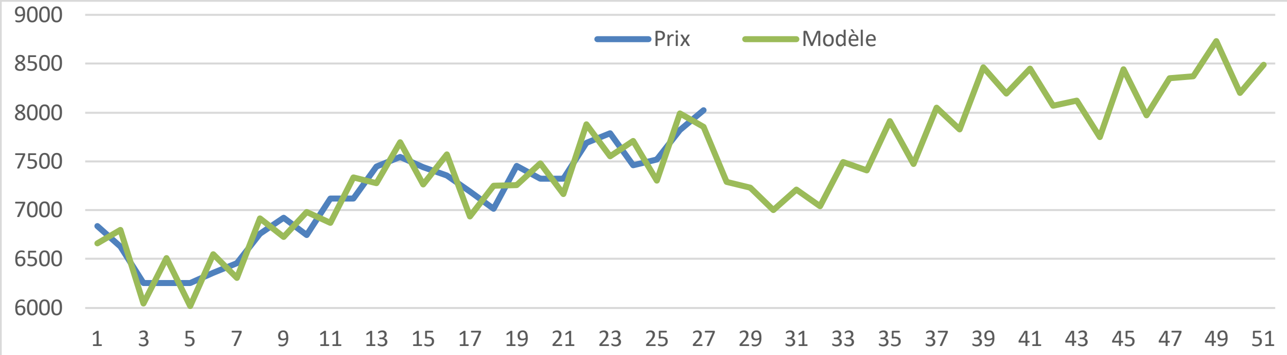

Figure 2 Model of all frequencies

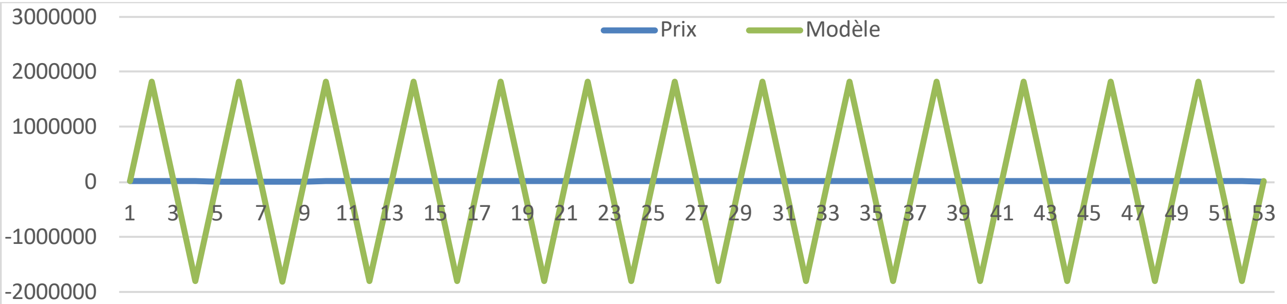

Figure 3 Oscillatory study of the model of all the frequencies

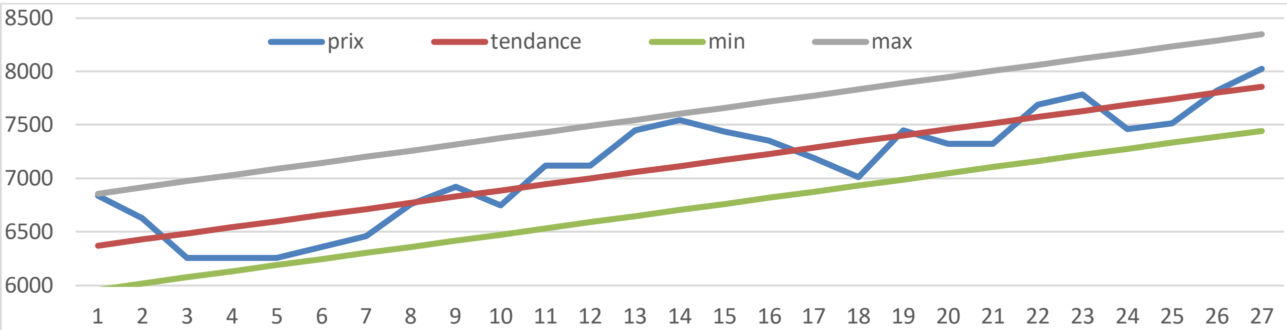

Figure 4 Low band filter

$$Y_t = a + bt + \sum_{i=1}^{p-2} A_i \cos(\omega_i t + \varphi_i) + e_t e_t \sim N(0, \sigma^2) \qquad (14)$$

To achieve the filter, we took the bandwidth so that all the elements of the series are between the minimum and the maximum of this one. So each A_i must be less than or equal to a constant (450 in our case). So we will have:

$$S_t = \sum_{i=1}^{\frac{p}{2}-1} A_i cos(\omega_i t + \varphi_i) \qquad (15)$$

Similarly, we will do an oscillatory study of the signal or the time series. The result is in figure 5.

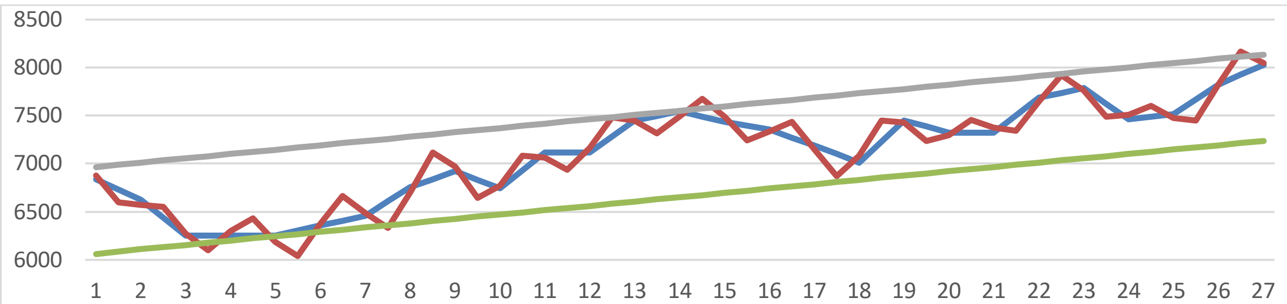

Figure 5 Oscillation study of the static filter

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The observed overruns are justified by the fact that we have made a naive assumption that the amplitudes must not exceed one constant sequentially. However, the damping effect of the other amplitudes must be considered. We must therefore consider the sum. Despite this, this filter already demonstrates excellent forecasting qualities. First, let's check the hypothesis that $\boldsymbol{e_t} \sim \boldsymbol{N}(\mathbf{0}, \boldsymbol{\sigma^2})$.

We perform tests on XLSTAT. For normality, we performed two tests, that are Kolmogorov-Smirnov and Khi². Results are grouped in Table 2 [21]:
H_0: The sample follows a Normal law.
H_1: The sample does not follow a Normal law.

Table 2 Normality tests of the static filter

Test		**Kolmogorov-Smirnov**		**Khi²**	**Degree of Freedom =6**
Parameter	Value	D	0.1178	Observed value	12.3801
µ	-0.0762	P-value	0.8239	Critical value	12.5916
Sigma	42.1218	Alpha	0.05	P-value	0.0540

Interpretations:

- *Kolmogorov-Smirnov:*

Since the calculated p-value is greater than the alpha threshold significance level = 0.05, the null hypothesis H_0 cannot be rejected. The risk of rejecting the null hypothesis H_0 when it is true is 82.39%.

- *Khi²:*

Since the calculated p-value is greater than the alpha threshold significance level = 0.05, the null hypothesis H_0 cannot be rejected. The risk of rejecting the null hypothesis H_0 when it is true is 5.40%.

The last test to be performed is the heteroskedasticity test [22]:

- *White's test:*

Table 3 White's Test

LM (Observed value)	0.6505
LM (Critical value)	5.9915
Degree of Freedom	2
P-value (bilateral)	0.7224
Alpha	0.05

Also, two hypotheses are formulated:
H_0: The residues are homoscedastic
H_1: The residues are heteroscedastic

Since the calculated p-value is greater than the alpha threshold significance level = 0.05, the null hypothesis H_0 cannot be rejected. The risk of rejecting the null hypothesis H_0 when it is true is 72.24%.

Although this static filter seems to provide very good results, it prompts us to think of a new filter that takes into account the aspect of amplitude attenuation: the birth of the dynamic filter.

3.5 Dynamic filter proposed

The idea of the filter is simple: to be able to get as close as possible to the time series with the minimum of oscillations. The figure 6 give us explanation of all this.

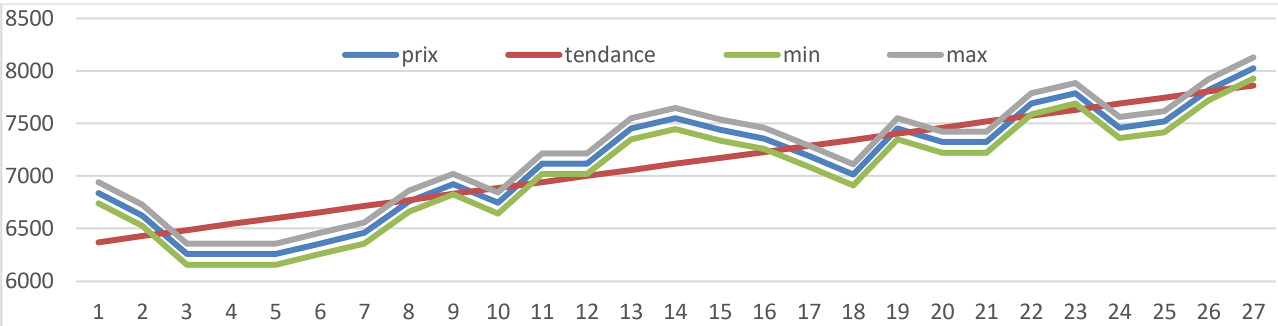

Figure 6 Dynamic filter construction

We will consider a parameter α so that the minimum and maximum are closest to the time series. The new seasonal component becomes:

$$\boldsymbol{S_t} = \sum_{i=1}^{\frac{p}{3}-1} \boldsymbol{A_i cos(\beta_i \omega_i t + \varphi_i)} \tag{16}$$

Because we will have new constraints: First: $-1 < \beta_i \leq 1$ (for all i ranging from 1 to n)
This parameter is inspired by the wavelet theory, notably the Morlet wavelet.

The exponential form is set aside expressly so that there is no exponential envelope (reverse funnel effect) because the series is stationary around the trend.
Two other constraints are added to attenuate the signal or the time series.

$$\sum_{i=1}^{n} \boldsymbol{A_i} + \boldsymbol{\alpha} \leq \mathbf{max}\,(\boldsymbol{y_t}) \tag{17}$$

$$\sum_{i=1}^{n} \boldsymbol{A_i} - \boldsymbol{\alpha} \geq \mathbf{min}\,(\boldsymbol{y_t}) \tag{18}$$

According to these new constraints the number of allowed sinusoids becomes: $\mathbf{n} = \frac{\mathbf{p}}{\mathbf{3}}\,\mathbf{-1.}$

The first remark is that this filter is greedy and it should only be used in case of significant observations! Secondly, this filter creates a compromise between the loss of information and the attenuation of oscillations. So we have to make sure that $e_t \sim N(0, \sigma^2)$. Results after applying this filter are presented in Figure 7. The test results are grouped in Table 4.

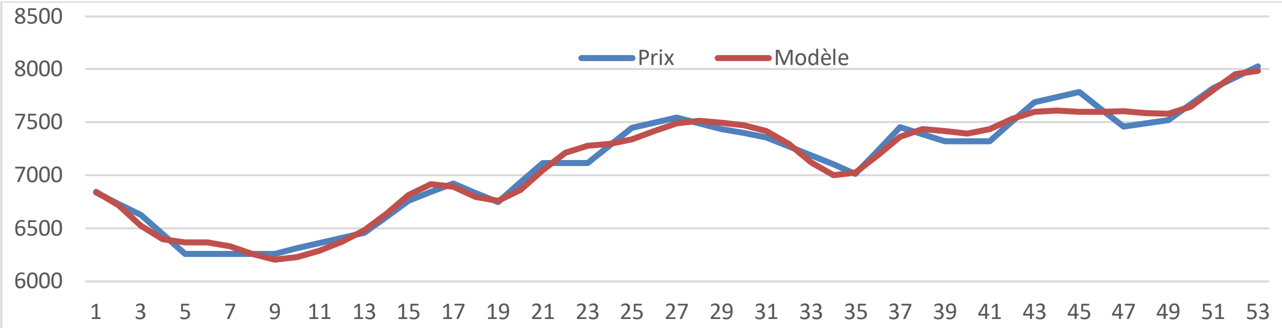

Figure 7 Dynamic filtering

Table 4 Normality tests of the dynamic filter

Estimated parameters		Kolmogorov-Smirnov		khi^2 Degree of Freedom=2	
Parameter	Value	D	0.0994	Observed value	0.5926
μ	0.2795	P-value	0.9410	Critical value	3.8415
Sigma	86.3681	Alpha	0.05	P-value	0.4414

Interpretations:
H_0: The sample follows a Normal law.
H_1: The sample does not follow a Normal law.

- *Kolmogorov-Smirnov:*

Since the calculated p-value is greater than the alpha threshold significance level = 0.05, the null hypothesis H_0 cannot be rejected. The risk of rejecting the null hypothesis H_0 when it is true is 94.04%.

- *Khi^2:*

Since the calculated p-value is greater than the alpha threshold significance level = 0.05, the null hypothesis H_0 cannot be rejected. The risk of rejecting the null hypothesis H_0 when it is true is 44.14%.

- *White's test (Table 5)*

Table 5 White's Test

LM (Observed value)	3.3172
LM (Critical value)	5.9915
Degree of Freedom	2
P-value (bilateral)	0.1904
Alpha	0.05

H_0: The residues are homoscedastic
H_1: The residues are heteroscedastic

Given that the calculated p-value is greater than the threshold level of significance alpha = 0.05, we cannot reject the null hypothesis H_0. The risk of rejecting the null hypothesis H_0 when it is true is 19.04%.

We note that the dynamic filter makes it possible to normalize the residues with a very good power (94% for the Kolmogorov-Smirnov test), but there is a risk that these residues are heteroscedastic opposite to the static filter.

3.6 *Comparison between the static filter and the dynamic filter*

3.6.1 Oscillation study

Similarly, through Shannon's theorem and interpolation we obtain the result presented in figure 8. It is clear that the oscillations are much better attenuated by the dynamic filter which makes the curve much smoother.

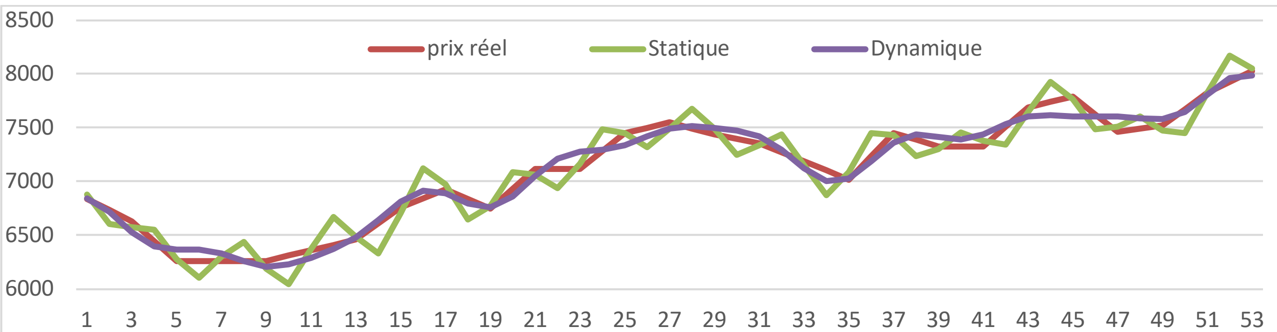

Figure 8 Oscillatory study of static and dynamic filtering

3.6.2 Forecast Horizon

Since both models are stationary around the trend, we can broaden the forecast horizon until a new cycle appears. The figure 9 shows the result of the two filters. The two filters give asymptotically equal series for the first two years then there is a shift! The new harmonic dynamic regression model is under the form of an optimization problem. The proposed new model is in (19).

$$\mathbf{Min}\ Y_t = a + bt + \sum_{i=1}^{\frac{p}{3}-1} A_i \cos(\beta_i \omega_i t + \varphi_i) + e_t e_t \sim N(0, \sigma^2 \qquad (19)$$

$$(\textit{Under Constraints}) \begin{cases} \sum_{i=1}^{\frac{p}{3}-1} A_i \cos(\beta_i \omega_i t + \varphi_i) + \alpha \leq \max(y_t) \\ \sum_{i=1}^{\frac{p}{3}-1} A_i \cos(\beta_i \omega_i t + \varphi_i) - \alpha \geq \min(y_t) \\ -1 \leq \beta_i \leq 1 \end{cases}$$

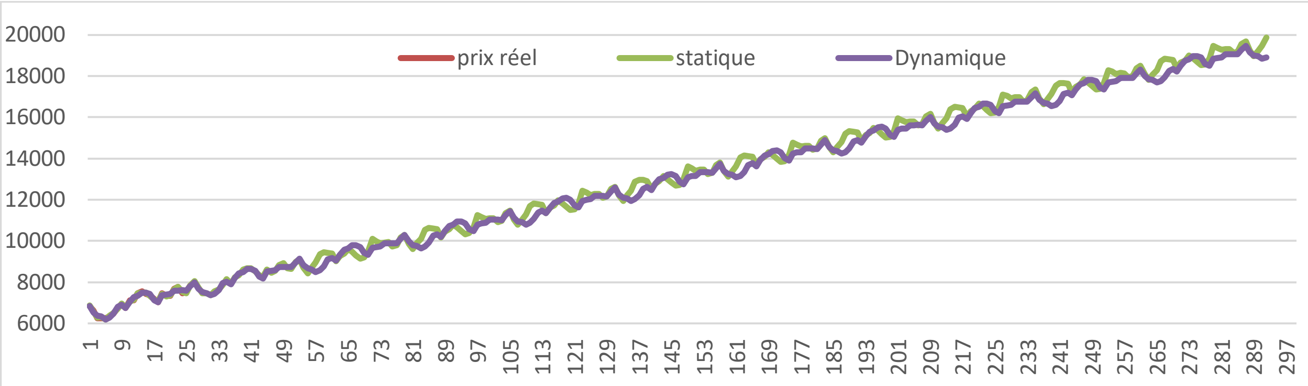

Figure 9 Forecast horizon for both filters

Since it is difficult to implement this model, we propose to work using the numerical model in (20).

$$\mathbf{Min}\ Y_t = a + b * t + \sum_{i=1}^{\frac{p}{3}-1} A_i * \cos(\beta_i * \omega_i * t + \varphi_i) + e_t e_t \sim N(0, \sigma^2) \qquad (20)$$

$$(\textit{Under Constraints}) \begin{cases} \sum_{i=1}^{\frac{p}{3}-1} A_i + \alpha \leq \max(y_t) \\ \sum_{i=1}^{\frac{p}{3}-1} A_i - \alpha \geq \min(y_t) \\ -1 \leq \beta_i \leq 1 \end{cases}$$

In this section, we have developed the basics of the new harmonic dynamic regression model, while performing various tests to validate the proposed model. This study has focused on the price of diesel fuel duty free and the conclusive results push us to test it on the price of SSP " Super Sans Plomb" all taxes included.

4 Case study

In this section, we will focus on in-depth SSP prices to determine the best possible DHR-based forecasting model. We will be constrained by the total permissible margin of the order of 3% which corresponds to our tolerance interval.

4.1 General model

In this first part, we will model, through the HDR, the prices of the last four years. The result found is presented in figure 10.

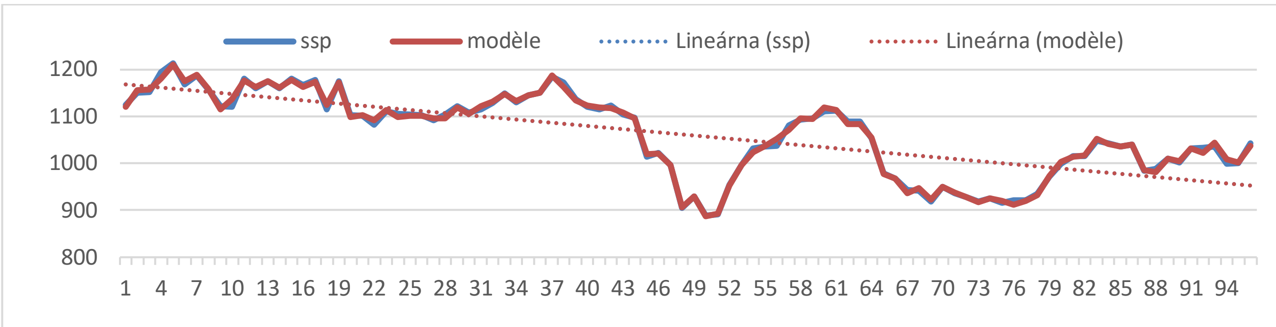

Figure 10 Model of the last 4 years

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We will test the hypothesis of normality of errors through Khi²and Kolmogorov-Smirnov tests:
H_0: The sample follows a Normal law.
H_1: The sample does not follow a Normal law.

Table 6 Normality test

Test		Kolmogorov-Smirnov		Khi² Degree of Freedom =2	
Parameter	Value	D	0.1104	Observed value	0.7108
μ	0.0012	P-value	0.7009	Critical value	5.9915
Sigma	0.4782	Alpha	0.05	P-value	0.1805

Table 7 White's Test

LM (Observed value)	2.2118
LM (Critical value)	5.9915
Degree of Freedom	2
P-value (bilateral)	0.3309
Alpha	0.05

Interpretations

- Kolmogorov-Smirnov test:

Since the calculated p-value is greater than the alpha threshold significance level = 0.05, the null hypothesis H_0 cannot be rejected.
The risk of rejecting the null hypothesis H_0 when it is true is 70.09%.

- Khi² test:

Since the calculated p-value is greater than the alpha threshold significance level = 0.05, the null hypothesis H_0 cannot be rejected.
The risk of rejecting the null hypothesis H_0 when it is true is 18.05%.

- Heteroskedasticity test:

H_0: The residues are homoscedastic
H_1: The residues are heteroscedastic

Since the calculated p-value is greater than the alpha threshold significance level = 0.05, the null hypothesis H_0 cannot be rejected. The risk of rejecting the null hypothesis H_0 when it is true is 33.09%.
The next step will be to make price projections for the SSP based on this general model.

4.2 Forecasts from the general model

One-time forecasts

From the data of the last four years, we have been able to calculate the following RDH model shown in Figure 11.

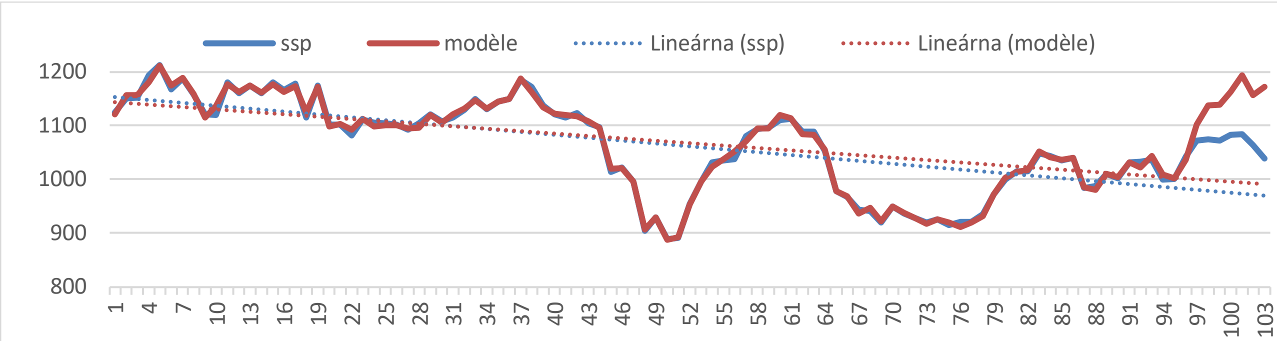

Figure 11 Predictions from the general model

Here are the results of the first quarter forecast summarized in Table 8.

Table 8 Forecast Results

Fortnight	Real Price	Model	% Error
1Q January	1072	1101.89	2.788246
2Q January	1074	1137.86	5.945996
1Q February	1072	1138.83	6.234142
2Q February	1082	1162.02	7.395564
1Q March	1084	1193.62	10.11255
2Q March	1064	1156.71	8.713346

The results obtained were not satisfactory compared to the tolerated margin of at least 3%. This is mainly due to data from the last three years before 2016 where the price was set by the state. Also, the compensation fund played a major role in covering the excessive increases in the price of a barrel on an international scale.

We therefore have only one year's data to make the predictions, i.e. 24 observations.

Forecast by confidence interval

Current forecasts are built for a 95% confidence interval.

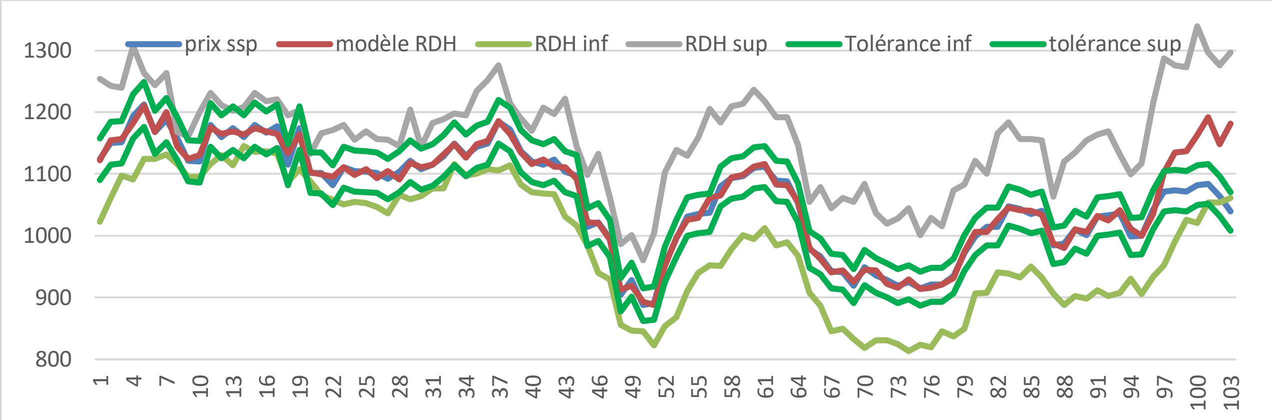

Figure 12 Confidence interval forecasts of the general model

4.3 Model reduced

To be able to work with data from a single year, we must choose between two approaches:

- Static filtering
- Dynamic filtering

We decided to compare between the two approaches.

4.3.1 Static filtering

Figure 13 reflects the results found.

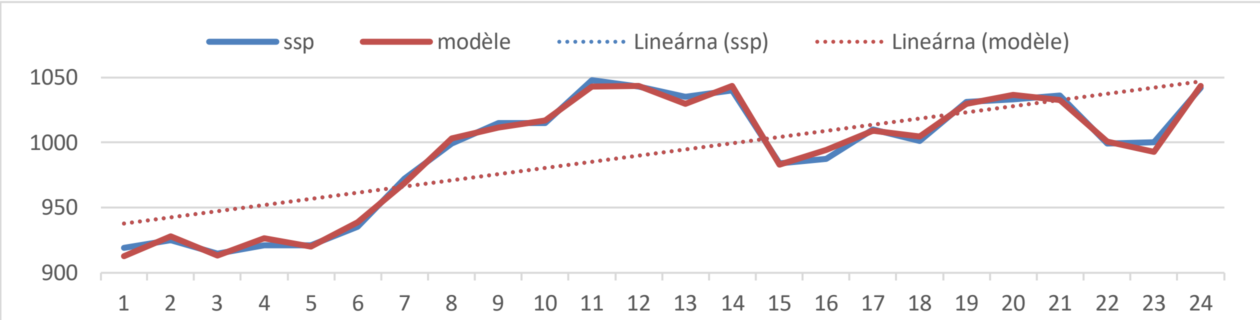

Figure 13 Static model

H_0: The sample follows a Normal law
H_1: The sample does not follow a Normal law

Table 9 Normality test results

Test		Kolmogorov-Smirnov		Khi^2 Degree of Freedom =2	
Parameter	Value	D	0.1251	Observed value	2.0978
µ	-0.0004	P-value	0.3503	Critical value	5.9915
Sigma	0.3962	Alpha	0.05	P-value	0.825

- Kolmogorov-Smirnov test:

Since the calculated p-value is greater than the alpha threshold significance level = 0.05, the null hypothesis H0 cannot be rejected.
The risk of rejecting the null hypothesis H_0 when it is true is 82.5%.

- Khi^2 test:

Since the calculated p-value is greater than the alpha threshold significance level = 0.05, the null hypothesis H_0 cannot be rejected.
The risk of rejecting the null hypothesis H_0 when it is true is 35.03%.

- Heteroskedasticity test:

Table 10 White's Test

LM (Observed value)	1.1608
LM (Critical value)	5.9915
Degree ofFreedom	2
P-value (bilateral)	0.5597
Alpha	0.05

H_0: The residues are homoscedastic
H_1: The residues are heteroscedastic

Since the calculated p-value is greater than the alpha threshold significance level = 0.05, the null hypothesis H_0 cannot be rejected. The risk of rejecting the null hypothesis H_0 when it is true is 55.97%.

Predictions from the static model

• One-time forecasts

The forecast results for the first quarter are summarized in Table 11.

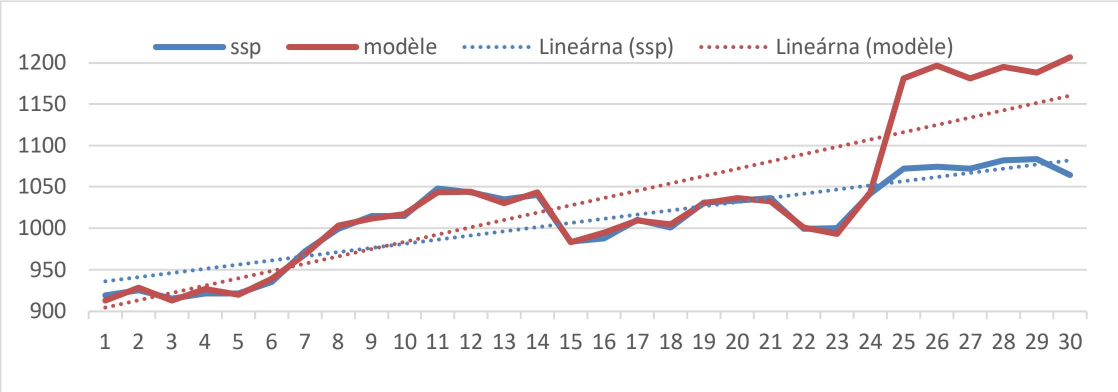

Figure 14 Static filter predictions

Table 11 Static filter prediction results

Fortnight	Real Price	Model	% Error
1Q January	1072	1180.96	10.16433323
2Q January	1074	1196.05	11.36442522
1Q February	1072	1180.91	10.16710017
2Q February	1082	1194.66	10.41225348
1Q March	1084	1187.98	9.592779328
2Q March	1064	1206.78	13.41920589

These results are not at all satisfactory and the percentage of error large enough is explained by the fact that the variables are overestimated and therefore there is a fairly large oscillation between two observations.

• Forecast by confidence interval

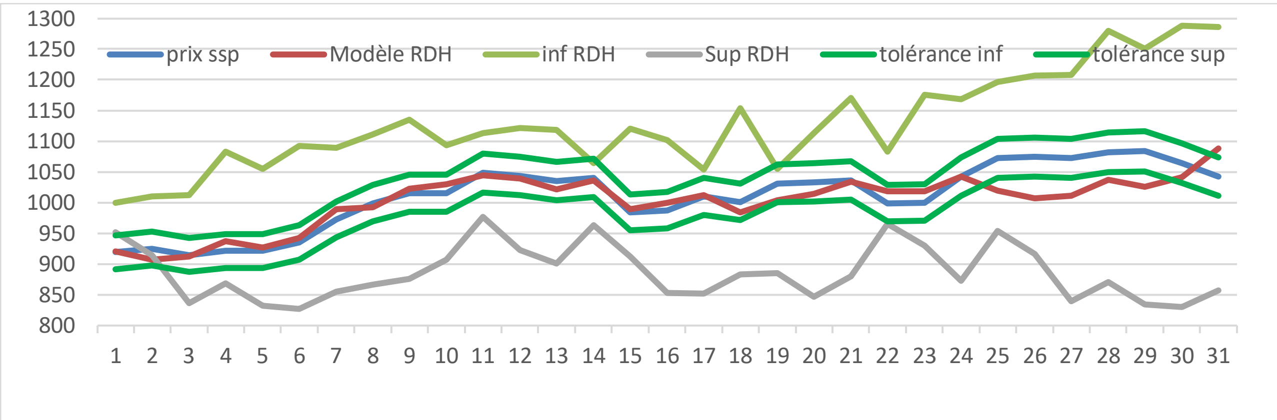

Figure 15 Forecast by confidence interval of the static model

4.3.2 Dynamic filtering

The found results are shown in Figure 16.

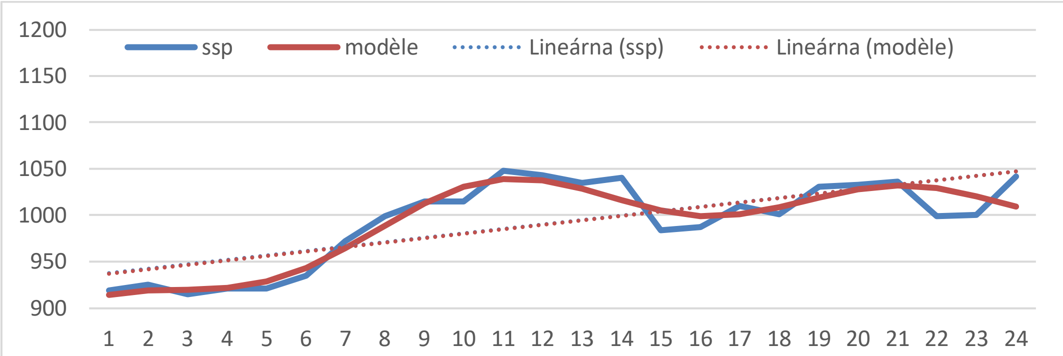

Figure 16 Dynamic Filter Results

H_0: The sample follows a Normal law
H_1: The sample does not follow a Normal law

Table 12 Normality test results

Test		Kolmogorov-Smirnov		Khi^2 Degree of Freedom =2	
Parameter	Value	D	0.1458	Observed value	2.7145
μ	-0.0189	P-value	0.2574	Critical value	5.9915
Sigma	1.4038	Alpha	0.05	P-value	0.6526

- Kolmogorov-Smirnov test:

Since the calculated p-value is greater than the alpha threshold significance level = 0.05, the null hypothesis H0 cannot be rejected.
The risk of rejecting the null hypothesis H_0 when it is true is 65.26%.

- Khi^2 test:

Since the calculated p-value is greater than the alpha threshold significance level = 0.05, the null hypothesis H_0 cannot be rejected.
The risk of rejecting the null hypothesis H_0 when it is true is 25.74%.

- Heteroskedasticity test:

Table 13 White's Test

LM (Observed value)	9.6522
LM (Critical value)	5.9915
Degree ofFreedom	2
P-value (bilateral)	0.0080
Alpha	0.05

H_0: The residues are homoscedastic
H_1: The residues are heteroscedastic
Interpretations:

Since the calculated p-value is less than the significance level alpha = 0.05, the null hypothesis H_0 must be rejected, and the alternative hypothesis H_1 must be accepted. The risk of rejecting the hypothesis H_1 when it is true is less than 0.80%.

Predictions from the dynamic model

• One-time forecasts

The results of the first quarter forecast are summarized in Table 14.

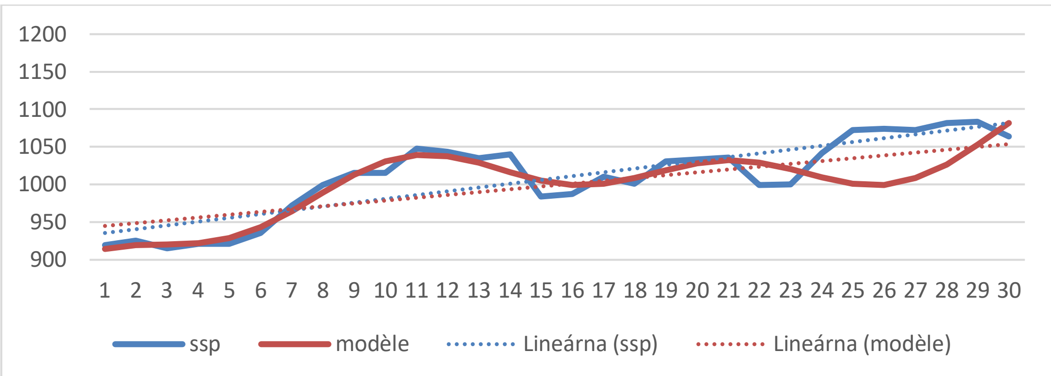

Figure 17 Dynamic Model Forecasts

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Table 14 Dynamic filter prediction results

Fortnight	Real Price	Model	% Error
1Q January	1072	1000.899217	-6.632535701
2Q January	1074	999.5125295	-6.935518669
1Q February	1072	1008.11424	-5.959492561
2Q February	1082	1026.784783	-5.103069996
1Q March	1084	1052.821886	-2.876209805
2Q March	1064	1081.646185	1.658476047

These results are still far from the margin of 3% fixed. This leads us to review our method to make changes.

• Forecast by confidence interval

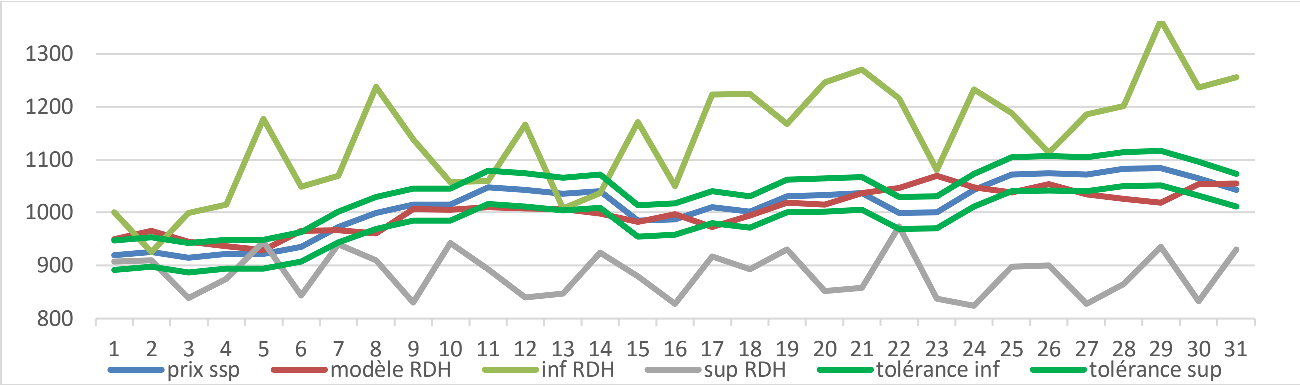

Figure 18 Confidence interval forecasts for the dynamic model

4.4 *Process approach*

We have seen in the previous section the importance of a good data analysis. In addition, we found that the static and dynamic models do not give the same results. Also, we notice that the assumed linear trend of the model no longer follows the real regression line of the data. On these three points in addition to the fixed margin of 3%, we will try to build a process approach for DHR.

4.4.1 Data analysis

In the previous section, we assumed that the company adapted to the withdrawal of the compensation fund from the outset, but it took a gradual adaptation time of about 6 months. So we can only work with the data of the last 6 months or 12 observations. We will work with the static model.

4.4.2 Local Dynamic Harmonic Regression Model

Figure 19 shows the results found.

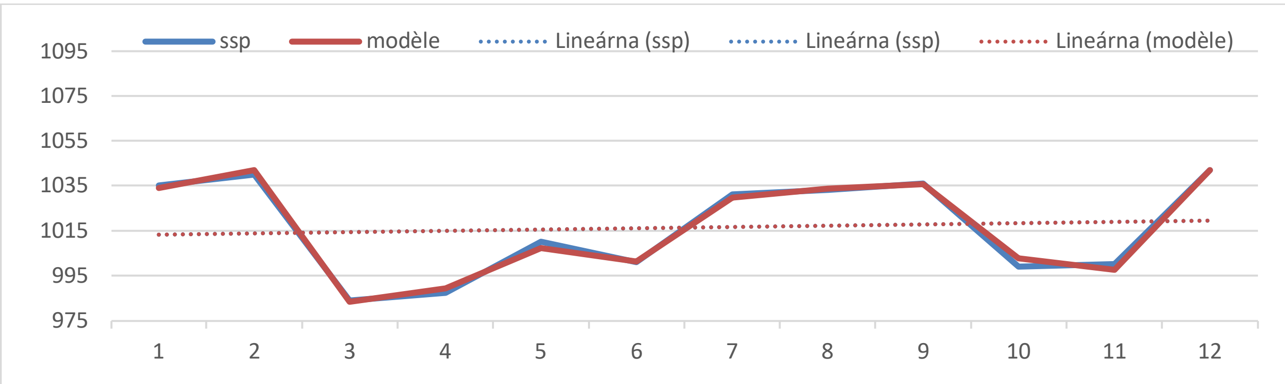

Figure 19 Local RDH Model

• Kolmogorov-Smirnov test:
H_0: The sample follows a Normal law
H_1: The sample does not follow a Normal law

Table 15 Normality test results

Test		Kolmogorov-Smirnov	
Parameter	Value	D	0.1288
µ	-0.0005	P-value	0.9818
Sigma	0.1812	Alpha	0.05

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Since the calculated p-value is greater than the alpha threshold significance level = 0.05, the null hypothesis H0 cannot be rejected.

The risk of rejecting the null hypothesis H_0 when it is true is 98.18%.

• Heteroskedasticity: White test:
H_0: The residues are homoscedastic
H_1: The residues are heteroscedastic

Table 16 White's Test

LM (Observed value)	0.6213
LM (Critical value)	5.9915
Degree of Freedom	2
P-value (bilateral)	0.7330
Alpha	0.05

Since the calculated p-value is greater than the alpha threshold significance level = 0.05, the null hypothesis H_0 cannot be rejected.

The risk of rejecting the null hypothesis H_0 when it is true is 73.30%. We can move to the forecasts now.

Table 17 Local Model Forecast Results

Fortnight	Real Price	Model	% Error
1Q January	1072	1000.899217	0.717024748
2Q January	1074	999.5125295	1.251208536
1Q February	1072	1008.11424	-4.004232553
2Q February	1082	1026.784783	-4.363472259
1Q March	1084	1052.821886	-2.873636521
2Q March	1064	1081.646185	-1.617299405

The new process approach is to adjust the model as forecasts are made by adjusting the parameters a and b. Indeed, we will readjust the trend of the model to each forecast so that it is as close as possible to the regression line of the quantitative variable. At each step, we must ensure that the predictions remain within the pre-defined tolerance interval (plus at least 3% in our case); otherwise we will have to recalculate the updated RDH model. If no update has been made after one-third of the observations (two months in our case), update the data.

Here is an explanatory diagram for this new approach shown in Figure 20.

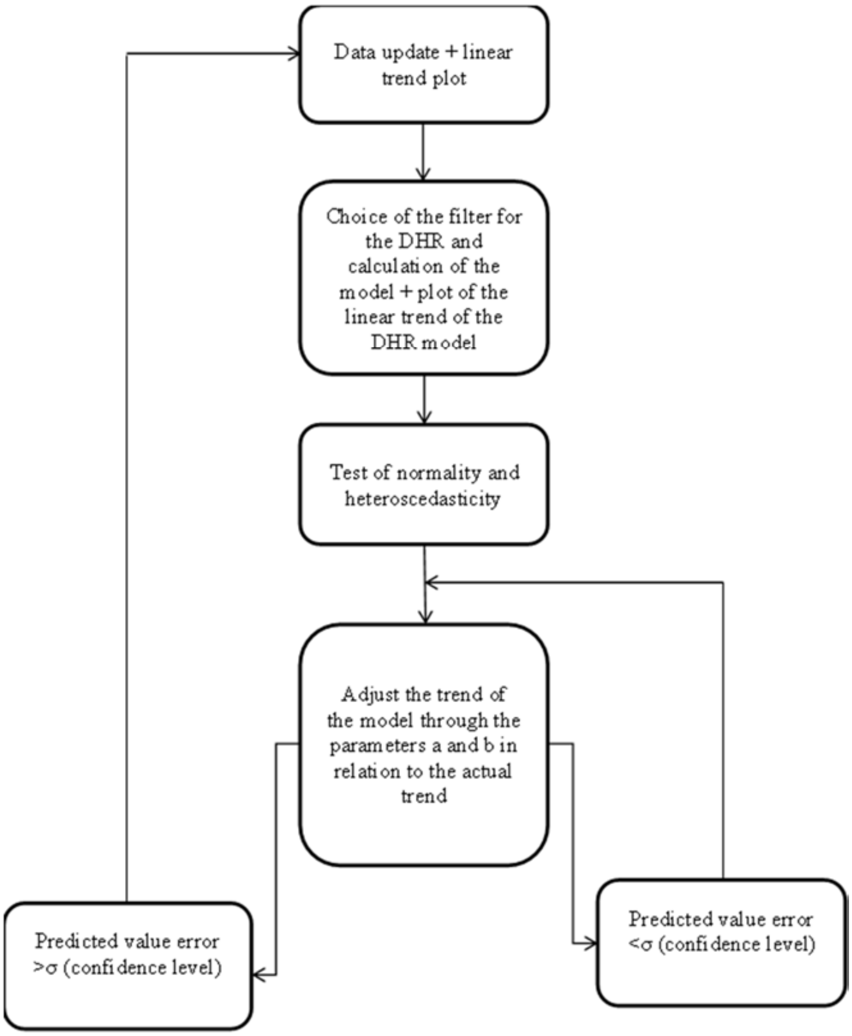

Figure 20 Process approach

4.5 Results of the process approach

In Table 18, we will list the values of the parameters a and b after each forecast. At t = 0, we modeled our data and did not make any predictions until then.

Table 18 First evolution of parameters a and b

t	**0**	**1**	**2**
a	991.813	993	995
b	3.802	3.55	3.2

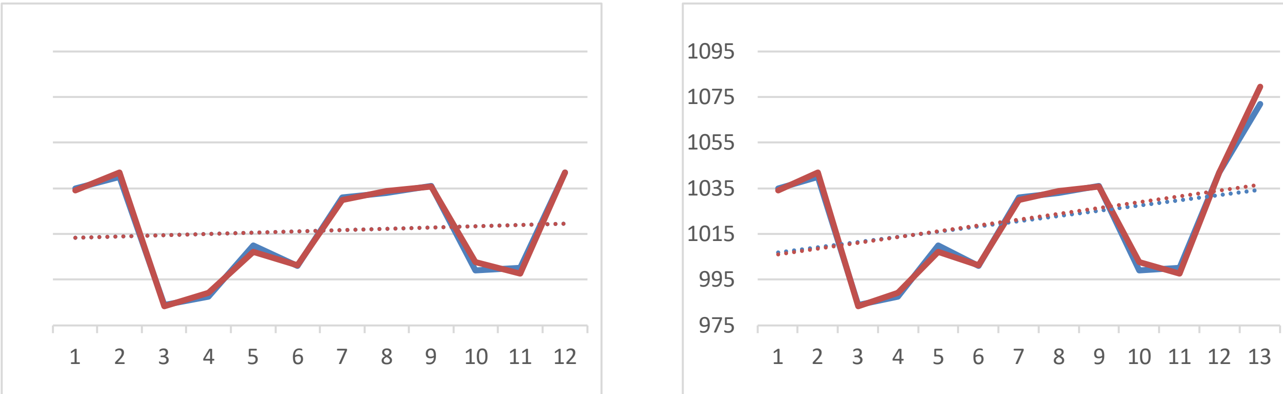

Figure 21 Prediction Using the Initial Model

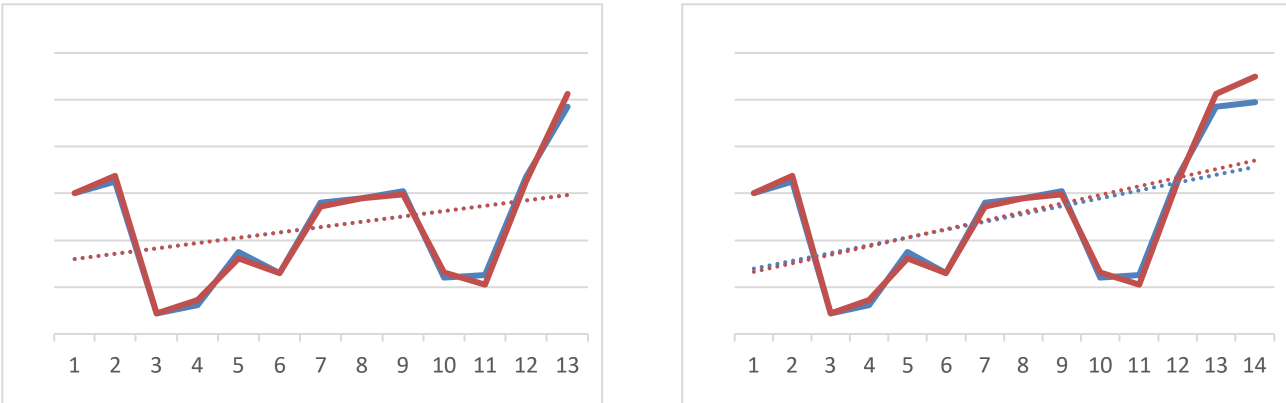

Figure 22 Forecast Using the Adjusted Model

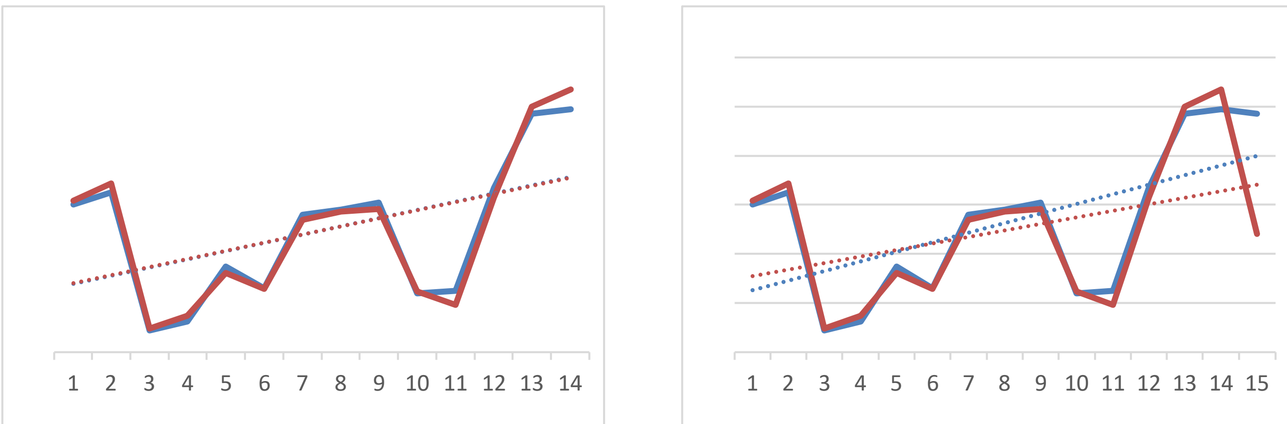

Figure 23 Forecast Using the Adjusted Model 2

Table 19 Forecast results

Fortnight	Real Price	Model	% Error
1Q January	1072	1079.686505	0.717024748
2Q January	1074	1085.09698	1.033238331
1Q February	1072	1023.231627	-4.549288523

It is now necessary to recalculate the model before making the forecasts of the next fortnights. To do this, we will integrate the last three measured values and therefore we will have 15 observations.

Here is the new DHR model shown in Figure 24.

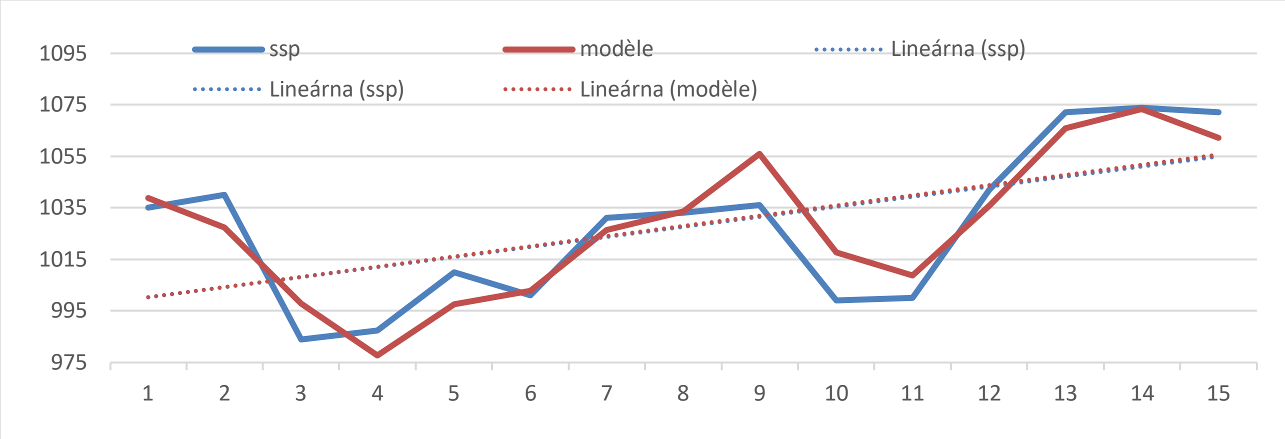

Figure 24 Updated DHR model

• Kolmogorov-Smirnov test:
H_0: The sample follows a Normal law
H_1: The sample does not follow a Normal law

Table 20 Normality test results

Test		Kolmogorov-Smirnov	
Parameter	Value	D	0.1420
μ	0.0428	P-value	0.9002
Sigma	1.0609	Alpha	0.05

Since the calculated p-value is greater than the alpha threshold significance level = 0.05, the null hypothesis H0 cannot be rejected.

The risk of rejecting the null hypothesis H_0 when it is true is 90.02%.

• Heteroskedasticity: White test:
H_0: The residues are homoscedastic
H_1: The residues are heteroscedastic

Table 21 White's Test

LM (Observed value)	1.1290
LM (Critical value)	5.9915
Degree of Freedom	2
P-value (bilateral)	0.5686
Alpha	0.05

Since the calculated p-value is greater than the alpha threshold significance level = 0.05, the null hypothesis H_0 cannot be rejected. The risk of rejecting the null hypothesis H_0 when it is true is 56.86%.

The table 22 summarizes the evolution of the parameters a and b.

Table 22: Second evolution of parameters a and b

t	**0**	**1**	**2**
a	1005.622	1005.622	1004
b	2.809	2.809	3.08

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Forecast results

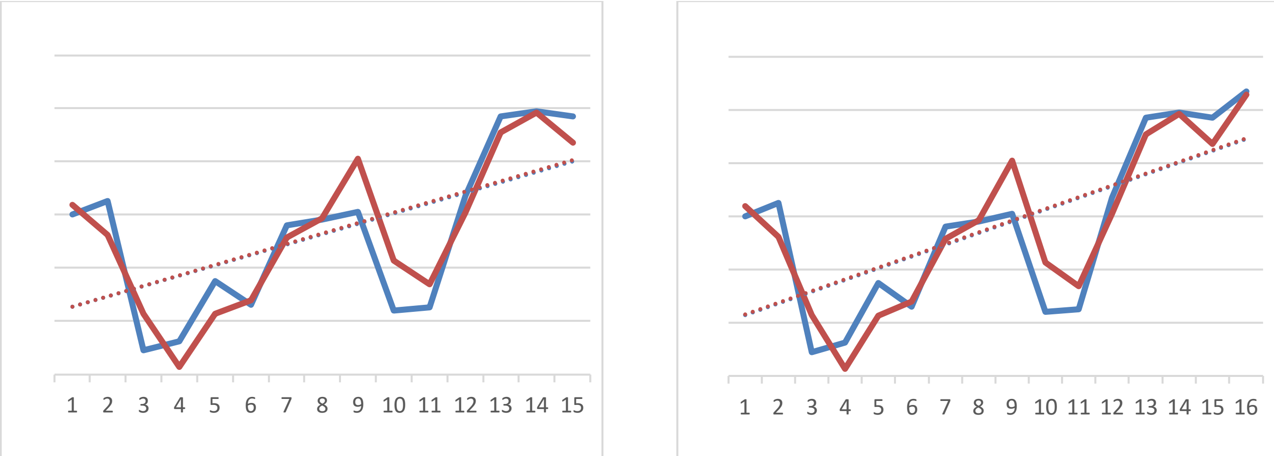

Figure 25 Prediction Using the Initial Updated Model

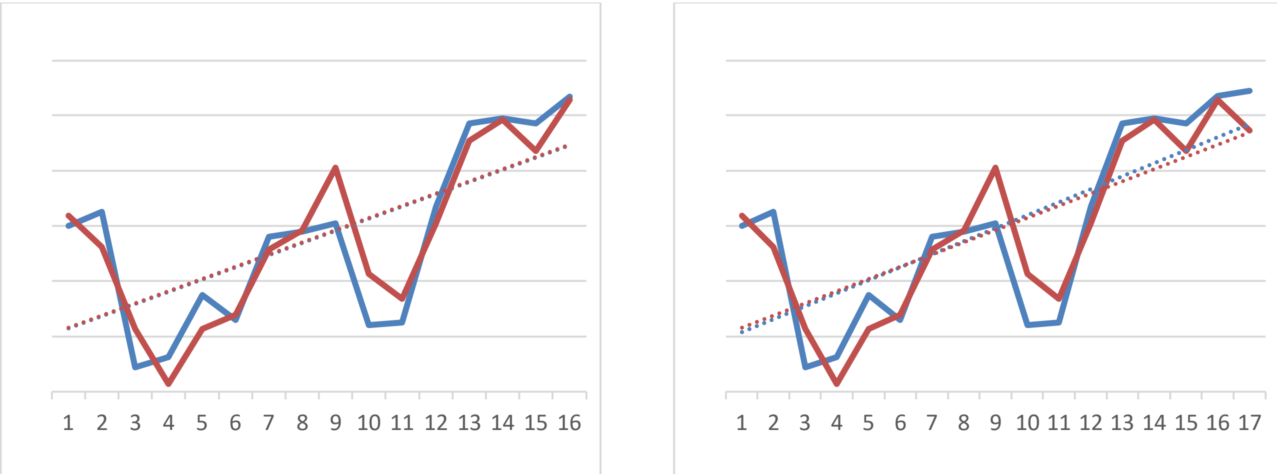

Figure 26 Forecast Using the Updated Updated Model 1

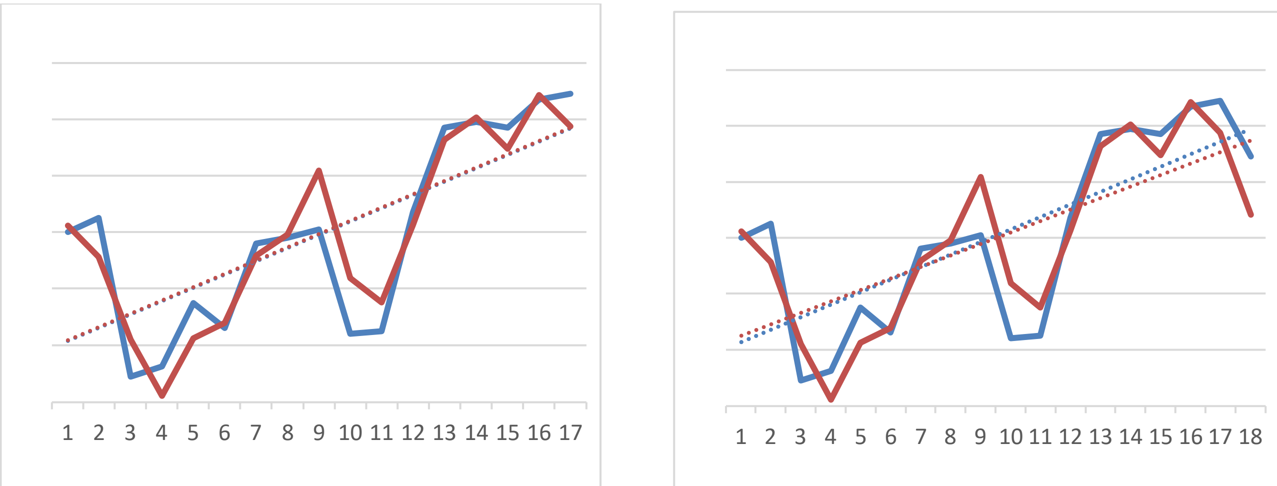

Figure 27 Forecast Using the Updated Updated Model

Table 23 Forecast results

Fortnight	Real Price	Model	% Error
2Q February	1072	1080.850305	-0.106256505
1Q March	1074	1072.436995	-1.342066846
2Q March	1072	1043.173202	-1.957405788

We have seen in this section that the DHR model does not only require the choice between the dynamic filter and the static filter, it must also make a rigorous analysis of the data and ensure that the objectives are achieved. This allowed us to put in place a process approach that proved to be very relevant for price analysis and forecasting of the SSP and thus, enable managers to take strategic decisions based on these accurate forecasts.

5 Conclusions

In this context, our work mainly aimed at studying the time series of diesel and SSP fuel in order to provide accurate forecasts and to respect the permissible margin of error of 3% setted by the company. For this purpose, we developed a new numerical method of harmonic dynamic regression. This new harmonic dynamic regression model through the proposed process approach yielded excellent forecast results for the first quarter of 2017 with an average margin error of 1.617%. We can therefore retain our model to make future forecasts, but each time we must feed our database to improve the results obtained. In this, the predicted performance can be evaluated, the best methodology and approach can be selected, and projections can be made. The increased predictions thus made will allow the managers to manage the business well in order to increase the income.

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TECHNIQUE FOR ESTIMATION OF COSTS AND PRICES IN CONTRACTS FOR THE INTERNATIONAL SALE OF GOODS BASED ON INCOTERMS®

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Keywords: Settlement prices, settlement costs, Incoterms®, SMEs, international sale of goods.
Abstract: The settlement of costs and prices in international business is an essential aspect of the competitiveness of internationalized companies. In this way, the "International Commercial Terms" (Incoterms)® as rules for the involved parties to a contract of international sale of goods become strategic, not only to define the conditions of delivery of the goods but also to define the value of an export according to the point of delivery within the international physical distribution chain. This study presents a detailed example of the costs derived from an international sale and purchase process, considering different databases published on the Internet, and provides a technique to simulate the value of each Incoterm 2020 rule. The results indicate the estimated prices for an export case from Colombia to the United States for containerized cargo. It is concluded that this technique facilitates the planning of the international sale and purchase, allowing to know the export values for each Incoterm, besides presenting an innovative model adaptable for other goods.

1 Introduction

In the last decades, the behaviour in the traffic of goods shipped around the world by type of cargo has had sustained growth, including the case of transport of goods by container. In this sense, cargo traffic has tripled from 3,304 million tons in 1974 to 11,076 million tons until the end of 2019. Similarly, in the last year, the world commercial fleet by type of vessel (tankers, bulk carriers, general cargo, container ships, among others) grew by 81 million deadweight tons (DWT) between January 2019 and January 2020 [1].

However, despite the impressive statistics of international trade in recent years, globalization is facing new challenges that intensify the panorama of uncertainty. Therefore, it is necessary to consider trade tensions such as those that occurred with the trade war between the United States and China and the challenges of geopolitics arising from differences in the foreign policy strategies of countries [2]. Likewise, problems such as the global public health difficulties arising from the recent pandemic, among many other aspects that impact the evolution of world trade and the international transport of goods [3-4].

Thus, considering all the previous challenges, digital technologies and information technologies take a significant role in improving productivity within organizations, favoring exchange processes and the signing of contracts with companies in other countries [5-7]. Likewise, the OECD [8] indicates that technologies and the internet can mitigate problems related to the environment, encourage the inclusion of societies and promote social development, especially in developing countries such as Latin America.

Thus, internationalized companies, including SMEs, should seek tools that facilitate the development of their logistics processes to effectively direct their goods to different markets in other countries [9]. For this reason, the objective of this document focuses on a technique for estimating costs and prices based on the "International Commercial Terms" (Incoterms)® version 2020, which is also applicable to international merchandise sales contracts. This technique also facilitates the determination of the export value of exclusively containerized goods according to their delivery point within the international logistics chain. This study addresses an export case of synthetic polymer paints due to the ease of grouping on pallets and the versatility of containers to transport them.

The case of containerized goods is considered because Incoterms® has been focused on adapting to contemporary commercial practices subject to the use of containers [10-11], and because of the current relevance of the container ships since sending goods through "Twenty-Foot Equivalent Units" (TEUs) and "Forty-Foot Equivalent Units" (FEUs) reach the second place of the total cargo of the world commercial fleet [1]. In this way, conclusions of the document constitute fundamental knowledge for further decisions in the management of cost and price settlement operations within international businesses.

2 Literature review

2.1 Incoterms and the logistics chain for settlement of costs and prices in the international sale of goods

International Commercial Terms (Incoterms®) have been since their creation in the mid-19th century in the 1930s, i.e., for almost a century of existence, an important issue and a recurring theme for the facilitation and regulation of the exchange of goods between companies of different nationalities involved in trade operations on a global scale. Thus, Incoterms® have allowed clarifying mainly the international logistic costs, among other essential commitments of the parties, delimiting then the responsibilities of both the seller and the buyer, thus reflecting the current practice in the transport of goods within the international physical distribution [12].

According to Cavaller [13], the International Chamber of Commerce (ICC), founded in France in 1919, has been in charge of Incoterms® since 1936. Then, different versions of the Incoterms® have been published in 1945, 1953, 1967, 1976, 1976, 1980, 1980, 1990, 2000, 2010, and 2020. Although it is necessary to point out, in any case, that the updating in all the versions of these terms, which seek to adapt to the changes that international trade is experiencing, does not mean invalidation of the previous versions since Incoterms® are retroactive. Hence, if the exporter and the seller by mutual agreement decide to use a version before the most recent one, they may do so since the rules do not repeal in time.

Thus, this set of uniform and complementary rules plays an essential role in the contract's configuration for the international sale of goods. Through these voluntarily accepted rules, the exporter and the importer can identify the commitments to fulfill according to their responsibilities related to logistics costs, documents, and physical risk to be assumed [14]. According to Anaya [15], Incoterms® represent an essential tool for commercial exchange planning in internalized enterprises by selling their products and buying raw materials within foreign markets. Therefore, Incoterms® manage to reduce uncertainty by clearly defining each party's role according to the point of delivery within the international logistics chain.

Incoterms® play such an essential role in the drafting of export and import contracts that the 1988 United Nations Convention on Contracts for the International Sale of Goods is still in force today. It provides the following statement in Part III, Sale of goods, section D, Passing of risk: "(...) the parties may regulate the issue in their contract either by an express provision or by the use of a trade term such as, for example, an Incoterm". It undoubtedly implies that these rules or terms of negotiation complement the contracts in anticipation of possible scenarios that could pose significant problems for the parties regarding the transfer of risk and liabilities [16].

For this reason, these rules can avoid interpretation differences that subsequently lead to complex commercial disputes in which the parties may lose money and time, hindering the international trade of goods. In other words, the essential function of Incoterms® is to establish a set of terms that act as a discretionary regulatory framework, which through its rules complements the international sales contract, thus allowing agree on some rights and obligations in different circumstances according to the capabilities of the parties [17].

Similarly, Incoterms® are considered an element of significant importance in settling both the cost and price of the goods to be traded. Therefore, the understanding of these negotiation terms depends on the international logistic chain itself since it represents the transport stages, from origin to destination, delimiting the risk transfer from the seller to the buyer [18]. According to Long [19], the international logistics chain generally groups the internal and external movements of an international sale and purchase of goods (see Table 1). Therefore, the management of this process represents a key factor for effective planning within the operations of internationalized companies, which seek to meet the demand in globalized markets and achieve the best possible results at affordable costs.

Therefore, each Incoterm 2020 version (see Table 2) will always be subordinated from their theoretical definition, which determines the place of transfer for the cargo within the international physical distribution process. It means that each of these rules offers a concrete alternative where the seller must leave the goods and where the buyer must receive them, which will end up defining the exact place to transfer risks, change goods' ownership and add logistics costs to the ex-factory price in the international logistics chain [27].

Table 1 Links and costs of the international logistics chain

N.	Node	Description	Related costs	Consultation web page
1	Exporter (EXP)	It is the company or natural person registered before the chamber of commerce in the country of origin to carry out commercial activities, including export operations from the Colombian customs territory to foreign countries. This is also often referred to within the commercial invoice as the shipper [20].	A. Packing, crating and leaving the goods ready for pickup.	https://bit.ly/3c9ebOq
2	Internal Transport of Origin (ITO)	It is the foreign trade company or operator, contracted by the exporter or importer according to the Incoterm, to move the container with the cargo from the exporter's facilities to the port of origin [21].	B. Loading of the merchandise in ITO. C. ITO loading insurance D. Cost of ITO (Medellin - Cartagena). E. ITO insurance. F. ITO unloading in POD with insurance included.	https://bit.ly/30l6wqJ
3	Customs of Origin (CUO)	It is a public organism located at strategic points in the exporter's country and its function is to supervise the outbound traffic of goods through the request of requirements and documents established by the customs legal system in force [22].	G. Hiring of the customs broker (processing of approvals and other documents).	https://bit.ly/3kUV9iL
4	Port of Origin (POR)	It is the physical space where both foreign trade operators and governmental institutions converge; all this, just before the goods are dispatched in international transport to another country. This place can be not only a seaport but also an airport or a land transport terminal [23].	H. POD costs (warehousing, handling, port taxes, etc.). I. Loading of goods at the INT and loading insurance.	https://bit.ly/3caoxgT
5	International Transport (INT)*	This is the process of moving the merchandise by the shipping line, airline or land carrier that moves the merchandise from the exporter's country to the importer's country. This activity can generate other costs such as insurance, fuel costs, issuance of documents and other associated costs [24].	J. Cost of the INT "Ocean Freight". K. All risk insurance and/or full coverage of the INT.	https://bit.ly/3egW3EU
6	Port of Destiny (POD)	It is the physical space in the destination country where both foreign trade operators and governmental institutions converge. This is the place where the merchandise arrives and where the process of nationalization and importation of the cargo begins, and it can be either a seaport, an airport or a land transport terminal [23].	L. TRI unloading in the POD. M. Insurance of unloading at POD, N. Costs at POD (storage, handling, port fees, etc.).	https://bit.ly/2OcYM7N
7	Customs of Destiny (CUD)	It is a public agency located in the importer's country whose function is to supervise the incoming traffic of goods through the request of requirements and documents established by the customs legal system in force. The customs also collect the tariffs that apply according to the type of merchandise and according to the existing international trade agreements [22, 25-26].	O. Hiring of the customs broker at destination. P. Ad-valorem Tariffs "Preferential tariffs must be considered according to the Free Trade Agreement (FTA) in force".	https://bit.ly/3kQS7Mu https://bit.ly/2PCEwwx
8	Internal Transport of Destiny (ITD)	It is the foreign trade company or operator, contracted by the exporter or importer according to the Incoterm, to move the container with the cargo from the port of destiny to the importer's facilities [21].	Q. Loading of goods in ITD. R. ITD cargo insurance S. ITD cost (Port Miami - final delivery point). T. ITD insurance.	https://bit.ly/3ecl306
9	Importer (IMP)	It is the company or natural person registered with the chamber of commerce in the country of destination of the merchandise to carry out commercial activities, including import operations. This is also usually known within the commercial invoice as the consignee [20].	U. Unloading of the goods at the final delivery point. V. Insurance of unloading of the goods at the final point.	https://bit.ly/3kRMOMG

**In this case, the technique for estimating costs and prices in contracts based on Incoterms® will be used for containerized cargo and will only apply to maritime transportation through shipping lines.*

Source: Authors

Table 2 Definition of Incoterms® for 2020 version

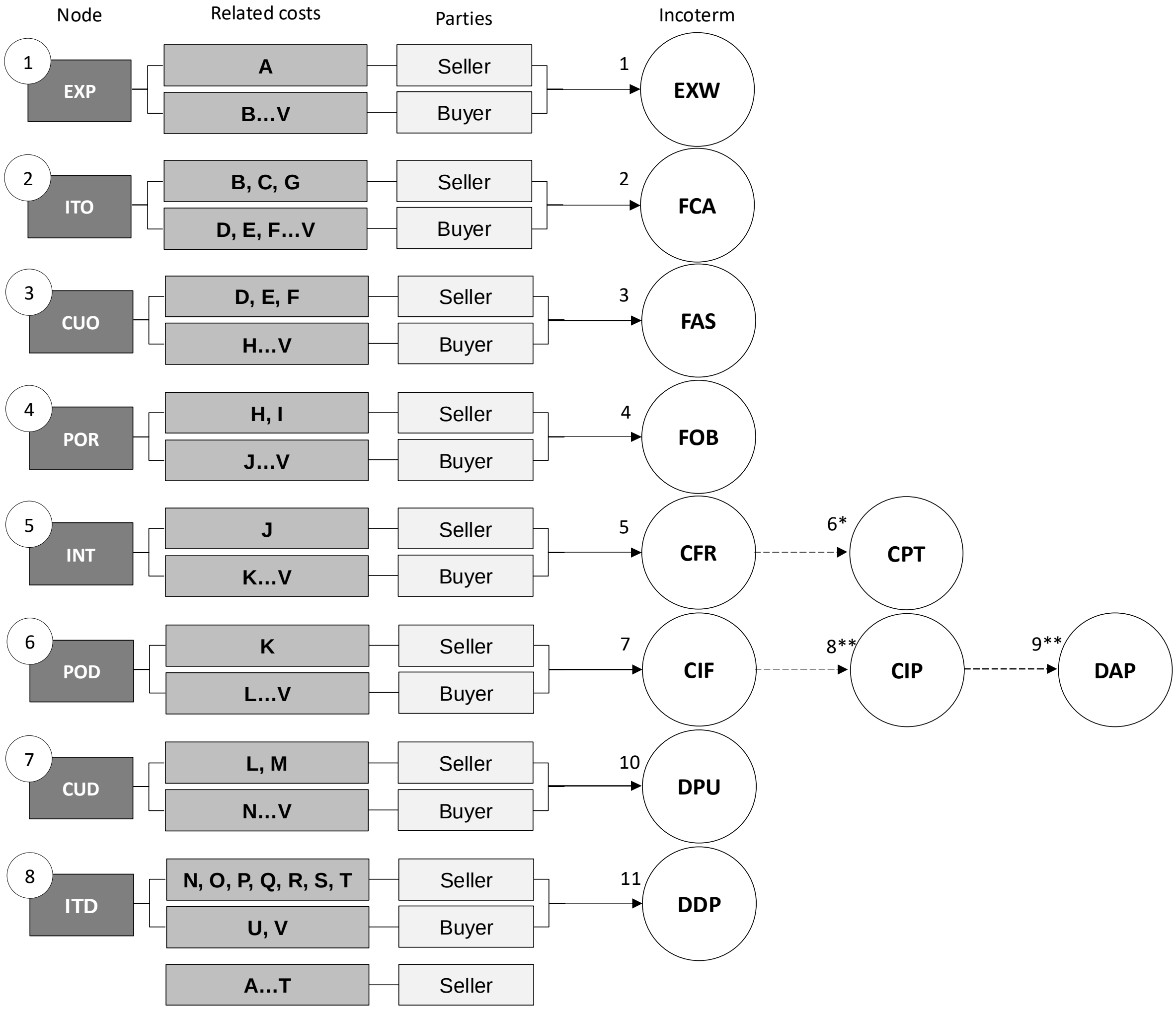
N.	Incoterm	Brief definition
1	***Ex Works* (EXW)**	The EXP will finish with its delivery responsibilities just when the goods have been placed in the warehouses of its own company packed and packed at the IMP disposal. Thus, the buyer will be responsible for loading the goods in the ITO and perform all other logistical operations in order to bring the goods to the facilities of his own company. This Incoterm places most of the responsibilities on the buyer who picks up the goods from the seller's warehouse and takes them to his facilities in the country of destination.
2	***Free Carrier* (FCA)**	The EXP must leave the goods in its warehouse. Similarly, he must carry out the documentary procedures with the CUO, in addition to assuming the costs and risk involved in loading the product in the ITO, which in this case will always be contracted by IMP, which in turn will be responsible for continuing with all the relevant processes until all the links in the international logistics chain have been overcome.
3	***Free Alongside* (FAS)**	The EXP must load the goods at the ITO in addition to hiring him directly. Then, he must move goods from his company to the POR and unload the merchandise at that place next to the vessel. On the other hand, the IMP will receive the cargo at the POR, and the IMP must also load the cargo on the vessel, which acts as the INT, and later carry out the necessary operations to take the goods to his own company in the country of destination.
4	***Free On Board* (FOB)**	The EXP is responsible not only for taking the goods to the POR but also for loading them at the INT, which in this term will be a motor vessel or ship, where its commitments end. Thus, the IMP must assume the responsibility of transporting the goods exclusively by sea, from the POR to the POD, and continue with the other stages of the international logistics chain.
5	***Cost and Freight* (CFR)**	The EXP must carry out the necessary processes to take and load the merchandise in the INT, in addition to assuming the costs generated by the transport operation, which in this term will be exclusively by maritime means. Similarly, the IMP will be responsible for acquiring international insurance to cover the journey from the POR to the POD. Likewise, IMP will have to carry out the rest of the operations until the merchandise arrives at its own company's facilities.
6	***Insurance and Freight* (CIF)**	The EXP will carry out all the necessary procedures to load the merchandise in the INT and pay this freight, which will always be with a shipping line since this rule must be used exclusively by maritime means. Likewise, the EXP must contract insurance for the INT to cover the merchandise in case of unforeseen events; despite the beneficiary of the insurance will be the IMP, who will also complete all the other necessary processes to take the merchandise to its facilities.
7	***Carriage Paid To* (CPT)**	This term has the same characteristics as the CFR Incoterm; therefore, the EXP must carry out all the necessary processes to take the goods to the POR and charge the goods to the INT, in addition to assuming the costs generated by the transport operation. Then, the IMP will be responsible for acquiring international insurance to cover the merchandise from the POR to the POD and subsequently take the goods to its own company's facilities. In any case, it is necessary to emphasize that this term, unlike the CFR used only through seagoing mode, can be used in the INT to move the goods by land, air, or sea.
8	***Carriage and Insurance Paid* (CIP)**	This term has the same characteristics as the CIF Incoterm; therefore, the EXP will carry out all the necessary procedures to load the merchandise at INT and pay this freight with its corresponding insurance covering the merchandise, making the beneficiary IMP. Likewise, the IMP will complete all the other processes to finalize the international logistic chain stages. However, it is necessary to emphasize that this term, unlike the CIF used only through seagoing mode, can be used in the INT to move the goods by land, air, or sea.
9	***Delivered At Place* (DAP)**	The EXP must take the goods to the POD or pointed agreed place in the IMP country; the above, with the INT´s insurance, included where the beneficiary will be the same seller. Thus, the goods must be prepared for unloading at the POD so that the buyer is in charge from this point to take it to its own facilities.
10	***Delivered At Place Unloaded* (DPU)**	This international negotiation term is the only rule inserted in the latest 2020 version. In this Incoterm, the seller is responsible for carrying out all the necessary operations from his company's facilities to unloading the goods at the POD in the buyer's country. There the goods must be unloaded from the arriving means of transport by EXP. Then the IMP will nationalize the goods with the CUD and take them to its warehouses by contracting the ITD.
11	***Delivered Duty Paid* (DDP)**	The EXP will finish with its delivery responsibilities when the merchandise has been taken to the country of destination, likewise, nationalized with the CUD paying the corresponding tariffs and finally contracting the ITD, leaving the merchandise at the disposal of the IMP in its facilities ready to be unloaded. Unlike EXW, this Incoterm places most of the sales contract's responsibilities over the seller, who takes the goods to the buyer's facilities, completing all the international logistic chain's nodes.

Source: Authors based on ICC [28]

In this regard, this article focuses on the Incoterms® 2020, considering that this version is the last one published by the ICC, adopting the present rules to the commercial practices of the current international trade [29]. Thus, the liquidation of the goods' prices for foreign markets will always follow the related costs derived from the different nodes of the international logistics chain. Therefore, these logistics costs determine the cargo's value reflected in the international sales contract and the commercial invoice [30]. Similarly, the inclusion of logistics costs that impact the final price of the export merchandise is the result of considering all those processes that must be performed and contracted with foreign trade operators to complete the international sale and purchase. In this sense, proper planning of international physical distribution and the negotiation of the Incoterms® will favor the competitiveness of the exported product's price [31].

3 Methodology

It is necessary to consider a scheme of the international physical distribution chain to develop a standardized technique to estimate costs and prices for international sales contracts, as described in Table 1. As shown in Figure 1, the scheme of the stages for an international sale and purchase process will facilitate the discrimination of the merchandise value according to the delivery point defined by the Incoterm agreed between the parties.



**Cost settlement and CFR and CPT price are the same.*
*** Cost settlement and CIF, CIP and DAP price are the same.*

Figure 1 Representation of Incoterms® within the international logistic chain according to the standard costs of an export or an import

Figure 1 shows that the number of related costs in the international logistics chain determines each Incoterm. Then, the first term, known as EXW, entails the lowest responsibility in terms of costs for the seller and the highest responsibility for the buyer. However, as the international physical distribution chain progresses, costs, and prices of merchandise increase; therefore, the last of these rules, known as DDP, entails the most significant responsibility for the seller and the lower responsibilities for the buyer. Therefore, the cost incurred by the EXP term from the manufacturing cost and the cost incurred in international trade in each Incoterm must be defined. The cost variables incurred by the EXP to calculate the cost of the merchandise are defined as follows:

Cost variables for EXP

C_{MP}: Merchandise raw material costs
C_{MO}: Merchandise labor costs
C_{CIF}: Manufacturing indirect costs
C_{MU}: Profit margin of the merchandise

Likewise, the cost variables incurred in international trade to calculate the settlement of the merchandise price in the different Incoterms is expressed below:

Cost variables to settle Incoterms®

C_B: Cost of loading the merchandise in ITO
C_C: ITO cargo insurance
C_D: ITO cost
C_E: ITO insurance
C_F: ITO download cost in POD, insurance included
C_G: Contracting costs of the Customs Agent at Origin (approvals and others) “0,5% EXW value"
C_H: Costs in POR (warehousing, handling, port fees, etc.)
C_I: Cost of loading freight at INT and cargo insurance
C_J: INT costs
C_K: All risk insurance and / or total INT coverage

C_L: Cost of unloading the INT in the POD
C_M: Download insurance in POD
C_N: POD costs (warehousing, handling, port fees, etc.)
C_O: Hiring the Customs Agent at Destination (Custom broker)
C_P: Ad-valorem Tariffs
C_Q: Cost of loading the merchandise in ITD
C_R: ITD cargo insurance
C_S: ITD cost (Port Miami - final delivery point)
C_T: ITD insurance

In order to distinguish the settlement values from the merchandise price in the different Incoterms®, the following settlement variables are used:

Price variables to settle de Incoterms®

V_{EXW}: Merchandise value in EXW
V_{FCA}: Merchandise value in FCA
V_{FAS}: Merchandise value in FAS
V_{FOB}: Merchandise value in FOB
V_{CFR}: Merchandise value in CFR
V_{CIF}: Merchandise value in CIF
V_{CPT}: Merchandise value in CPT
V_{CIP}: Merchandise value in CIP
V_{DAP}: Merchandise value in DAP
V_{DPU}: Merchandise value in DPU
V_{DDP}: Merchandise value in DDP

Therefore, the settlement value V_{EXW} is calculated using Equation (1), representing the value of the merchandise to be exported, including the costs of raw materials, labor, indirect manufacturing costs, and profit margin per unit.

$$V_{EXW} = C_{MP} + C_{MO} + C_{CIF} + C_{MU} \tag{1}$$

Once the settlement value V_{EXW} has been calculated, the basis for calculating the settlement value of the other Incoterms® is obtained, which successively will incur different cost variables related to foreign trade. Consequently, the settlement value V_{FCA} is calculated through Equation (2).

$$V_{FCA} = V_{EXW} + C_B + C_C + C_G \tag{2}$$

Equation (3) is used to calculate the V_{FAS} settlement value, which can take the V_{FCA} value as a reference and add the ITO cost, ITO insurance cost and ITO download cost in POD with insurance included.

$$V_{FAS} = V_{FCA} + C_D + C_E + C_F \tag{3}$$

The settlement value V_{FOB} can be based on the value V_{FAS}, to which the costs in POR and the costs of loading the merchandise in the INT and cargo insurance are added, as shown in Equation (4).

$$V_{FOB} = V_{FAS} + C_H + C_I \tag{4}$$

For the settlement values V_{CFR} and V_{CPT}, V_{FOB} is taken as a base to add the INT cost as shown in Equation (5) and Equation (6) respectively. The difference between V_{CFR} and V_{CPT} is that V_{CFR} exclusively considers international maritime transport, while V_{CPT} considers transportation by land, air, or sea.

$$V_{CFR} = V_{FOB} + C_J \tag{5}$$

$$V_{CPT} = V_{FOB} + C_J \tag{6}$$

In the case of the settlement values V_{CIF}, V_{CIP}, and V_{DAP}, the V_{CFR} value can be taken as a base when exclusively international maritime transport is considered, and the V_{CPT} value will be taken as a base when the transport mode is used independently. To these base values the cost of the all-risk insurance and/or total INT coverage is added, in such a way that the settlement value V_{CIF}, V_{CIP}, and V_{DAP} are calculated respectively with Equation (7), Equation (8), and Equation (9). The difference between V_{CIF} and V_{CIP} lies in the fact that the V_{CIF} is versatile while the V_{CIP} refers exclusively to transport by ship, whether maritime and/or fluvial. Similarly, V_{CIF} differs from V_{DAP} in that the insurance beneficiary is the buyer for the first case, and in the second case, the insurance beneficiary is the seller.

$$V_{CIF} = V_{CPT} + C_K \tag{7}$$

$$V_{CIP} = V_{CFR} + C_K \tag{8}$$

$$V_{DAP} = V_{CPT} + C_K \tag{9}$$

According to the aspects negotiated in the stages of international trade related to the settlement costs V_{CIF}, V_{CIP} and V_{DAP}, the settlement cost V_{DPU} can be calculated through Equation (10) by adding the INT download cost on POD and download insurance cost on POD.

$$V_{DPU} = \begin{cases} V_{CIF} + C_L + C_M \text{ } if\ the\ INT\ is\ polyvalent \\ V_{CIP} + C_L + C_M \text{ } if\ the\ INT\ is\ polyvalent \\ V_{DAP} + C_L + C_M \text{ } if\ the\ buyer\ is\ the\ beneficiary\ of\ INT's\ insurance \end{cases} \tag{10}$$

Equation (11) is used to calculate the settlement value V_{DDP}, which take as a reference the V_{DPU} value and add the

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POD costs, costs of hiring the customs broker, ad-valorem tariffs, costs of loading merchandise in ITD, loading insurance ITD, cost of ITD and insurance of ITD.

$$V_{DDP} = V_{DPU} + C_N + C_O + C_P + C_Q + C_R + C_S + C_T \quad (11)$$

On the other hand, identifying the stages in the international physical distribution process is essential for the proposed estimation technique (see Figure 2). The product to be exported in this study is "paints based on synthetic polymers dispersed or dissolved in an aqueous medium with tariff nomenclature 32.09.90". This product was identified as its general presentation, including packaging, packing, and certain physical-technical specifications related to the stowage on half pallets and the subsequent cubing in a forty-foot equivalent unit (FEU). The abovementioned allow planning the international physical distribution of the merchandise considered in this study. Within this technique, it is necessary to define the port of origin (POR) and the port of destiny (POD) according to the export circumstances, which in this case are represented by Cartagena Colombia (POR) and to Miami USA (POD).

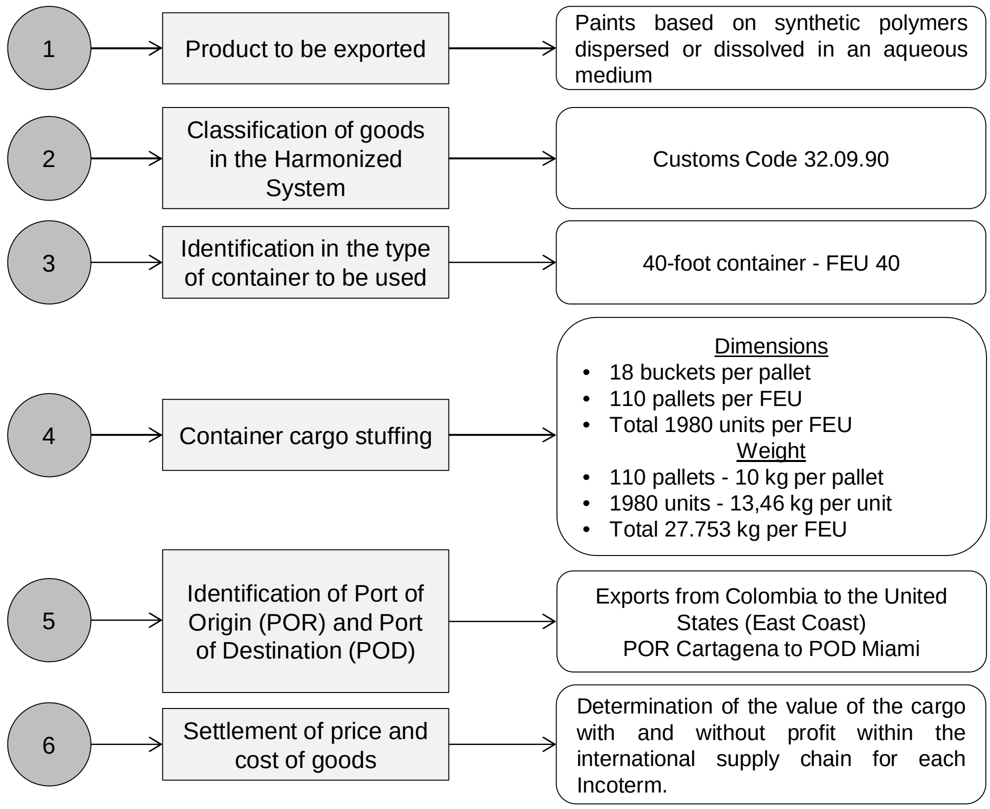

Figure 2 Stages for estimation of costs and prices in contracts for the international sale of goods

4 Result and discussion

The stowage process is performed according to the information of the export product, assigning products to pallets to facilitate their handling and transport in the international physical distribution chain. For this, Figure 3 shows the distribution of products in half Euro-pallets with measures of 0.8m x 0.6m x 0.14m in length, width, and height respectively, assigning six units per pallet level, and allowing to stow three layers of products, for a total of 18 units per pallet.

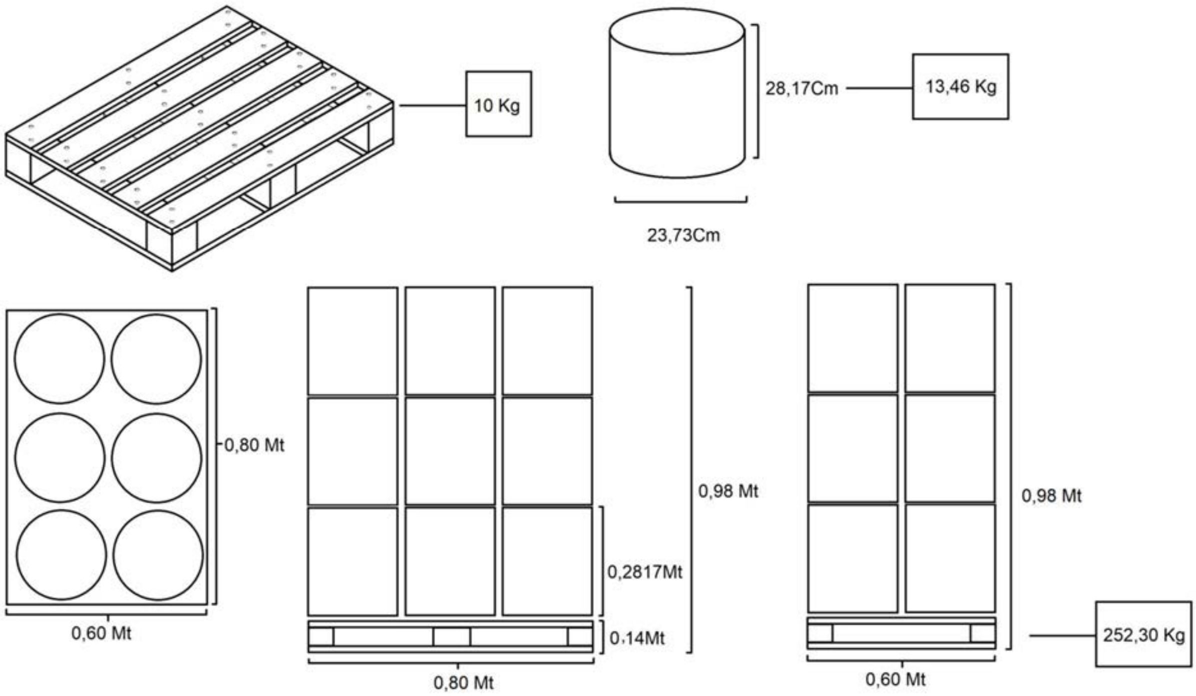

Figure 3 Buckets stowed per pallet

In order to optimize the available space in a 40ft container, which includes internal dimensions of 12.03m x 2.35mx 2.69m in length, width, and height respectively, a total of 55 pallets are assigned per level, and two stowage levels, for a total of 110 pallets, which allow the transport of 1.980 buckets, representing a net weight of 27.75 tons.

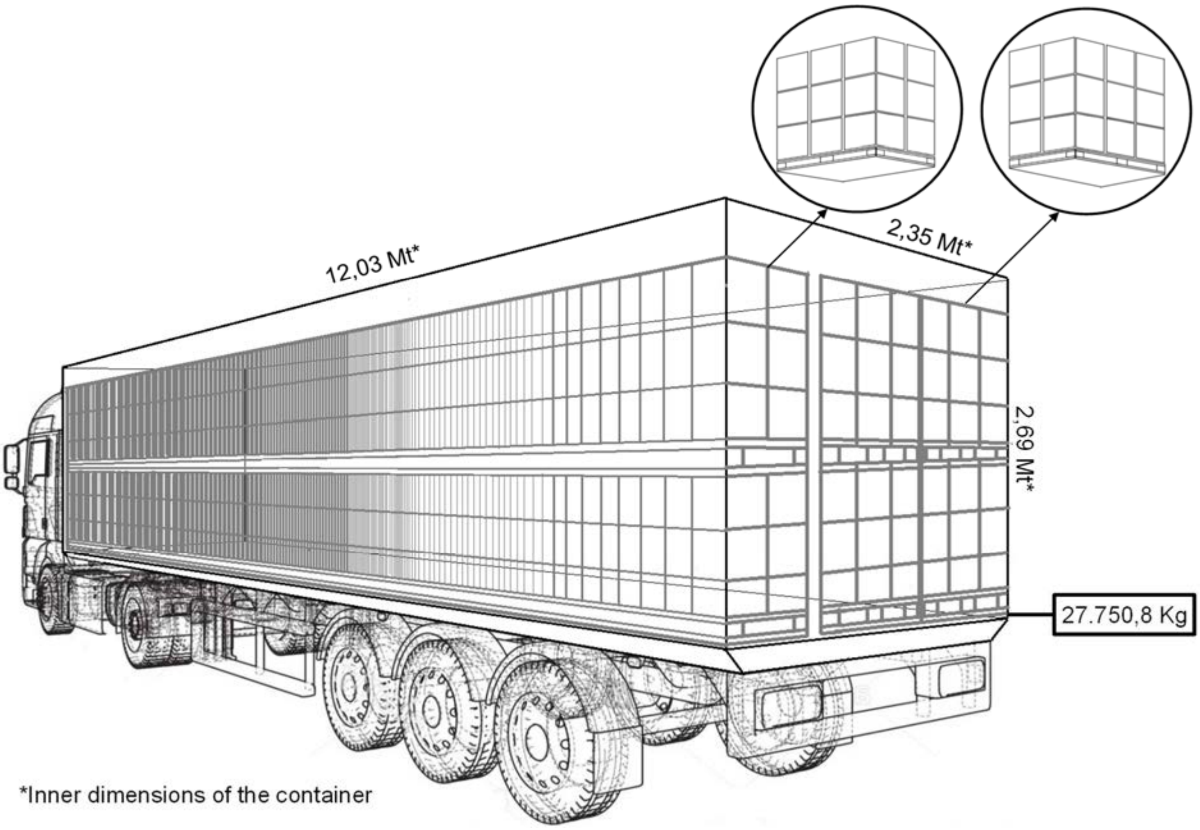

Figure 4 Cubing and stowage for paint buckets in FEU

In this way, the container occupancy is maximized to reduce the unit price in each Incoterm, which results from dividing the total settlement price by the number of export units. Therefore, it is possible to settle the price of each Incoterm considering the values of the cost variables shown in Table 3, which represent the input for Equations (1-11).

Table 3 Cost variables for Incoterms® settlement

Variable	Description	Value
C_{MP}	Merchandise raw material costs	$ 9,72
C_{MO}	Merchandise labor costs	$ 4,17
C_{CIF}	Manufacturing indirect costs	$ 5,56
C_{MU}	Profit margin of the merchandise	$ 5,56
C_B	Cost of loading the merchandise in ITO	$ 55,6
C_C	ITO cargo insurance	$ 13,9
C_D	ITO cost	$ 1.000,1
C_E	ITO insurance	$ 27,8
C_F	ITO download cost in POD, insurance included	$ 55,6
C_G	Contracting costs of the Customs Agent at Origin (approvals and others) “0,5% EXW value"	$ 247,5
C_H	Costs in POR (warehousing, handling, port fees, etc.)	$ 222,2
C_I	Cost of loading freight at INT and cargo insurance	$ 69,4
C_J	INT costs	$ 1.942,0
C_K	All risk insurance and / or total INT coverage	$ 97,2
C_L	Cost of unloading the INT in the POD	$ 83,3
C_M	Download insurance in POD	$ 27,8
C_N	POD costs (warehousing, handling, port fees, etc.)	$ 208,3
C_O	Hiring the Customs Agent at Destination (Custom broker)	$ 222,2
C_P	Ad-valorem Tariffs (if FTA agreements apply, then 0%, else 5,90%)	$ 3.140,6
C_Q	Cost of loading the merchandise in ITD	$ 27,8
C_R	ITD cargo insurance	$ 13,9
C_S	ITD cost (Miami Port - final delivery point)	$ 861,1
C_T	ITD insurance	$ 8,3

Consequently, Table 4 presents both the total price settlement and the unit price settlement for each Incoterm. Likewise, Table 4 shows the variation of the total price and unit price in each Incoterm compared to the base value of the EXW Incoterm, which is calculated using Equation 12. The results show that DDP receives the maximum variation with an increase of 16,82% on the merchandise price concerning the EXW, including there the main costs within the international logistics chain.

$$\%\Delta = \frac{V_{Incoterm} - V_{EXW}}{V_{EXW}} \tag{12}$$

Table 4 Price variables for Incoterms® settlement

Variable	Description	Total Price	Unit price	% Variation*
V_{EXW}	Merchandise value in EXW	$ 49.500	$ 25,00	0,00%
V_{FCA}	Merchandise value in FCA	$ 49.817	$ 25,16	0,64%
V_{FAS}	Merchandise value in FAS	$ 50.900	$ 25,71	2,83%
V_{FOB}	Merchandise value in FOB	$ 51.192	$ 25,85	3,42%
V_{CFR}	Merchandise value in CFR	$ 53.134	$ 26,84	7,34%
V_{CPT}	Merchandise value in CPT	$ 53.134	$ 26,84	7,34%
V_{CIF}	Merchandise value in CIF	$ 53.231	$ 26,88	7,54%
V_{CIP}	Merchandise value in CIP	$ 53.231	$ 26,88	7,54%
V_{DAP}	Merchandise value in DAP	$ 53.231	$ 26,88	7,54%
V_{DPU}	Merchandise value in DPU	$ 53.342	$ 26,94	7,76%
V_{DDP}	Merchandise value in DDP	$ 57.825	$ 29,20	16,82%

**Percentage of variation compared to EXW*

Therefore, the settlement formulations for Incoterms® proposed in this study allow us to calculate the total and unit prices to be assumed according to the responsibility and risk agreed upon, which depend on the buyer's ability to perform logistics activities. For the case study, the main increases in settlement prices correspond when changing from the Incoterm DPU to DDP, implying an increase of 8,4% in the merchandise price, represented in costs in POD, contracting the custom broker, Ad-valorem duties, loading merchandise in ITD, insurance of load in ITD, the expense of ITD, and insurance of ITD. Similarly, significant increases in merchandise settlement values of 3,8% correspond when moving from FOB Incoterm to CFR or CPT by incurring INT costs.

5 Conclusions

The technique developed in this article for the cost and price estimation in contracts for international trade can be used both for goods in containers and oversized goods that exceed the dimensions of standard containers used in international maritime transport. Likewise, the proposed technique can settle the price of goods transported by different means of international transport according to the values of each specific process within the global logistics chain and according to the nature of the Incoterm agreed between the exporter and the importer. Therefore, this study offers an easy-to-use tool to guide decision-making within the international logistics chain, providing information sources from the internet to obtain the cost variables to settle Incoterms. Similarly, this research establishes the settlement values for each Incoterm, considering the level of risks and responsibilities that the involved parties wish to assume.

Future works should apply the proposed formulations for different types of goods, points of origin, and destinations to establish the value variation generated between each Incoterms® according to the responsibilities assumed by each party. It is entirely feasible to reproduce the present technique with previous Incoterms® considering that these rules created by the ICC are retroactive, and if the parties to the contract agree, they can use versions before 2020; such as the 2010 version and the 2000 version, both still widely used in international trade operations.

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IMPROVING THE LEVEL OF PREDICTIVE MAINTENANCE MATURITY MATRIX IN INDUSTRIAL ENTERPRISE

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***Keywords*:** predictive maintenance, Predictive Maintenance Maturity Matrix, Industry 4.0, Logistics 4.0, case study.
Abstract: Predictive maintenance is a maintenance strategy that applies advanced statistical methods and artificial intelligence to determine the appropriate maintenance time. The article focuses on future recommendations for industry and logistics to achieve a higher level of predictive maintenance maturity, which requires real-time monitoring of the state of the company's machinery and equipment. The article's main objective is to propose recommendations to increase effectiveness by improving the predictive maintenance maturity matrix from the current level to a higher level in the industrial enterprise. The current state of maturity has been indicated using the modified model of predictive maintenance and following recommendations from the document Manual for companies for the introduction of artificial intelligence. Simultaneously within the analysis, a predictive maintenance simulation was performed on a selected production line, including essential machines and equipment. The study also identified the individual assumptions (processes, data, infrastructure, personnel, applications, organization) necessary to implement predictive maintenance successfully. The presented case study results contribute to understanding how individual assumptions can be obtained for predictive maintenance improvement and how innovative solutions in the context of Industry 4.0 and Logistics 4.0 can be achieved in enterprises.

1 Introduction

One of the critical tasks in industrial production and logistics is to reduce costs and eliminate waste. One of the identified wastes are often downtimes, which are related to not optimal set maintenance cycles. Reasons are that two extreme cases might occur: either service interventions are too frequent, which increases maintenance costs or maintenance is neglected, which can lead to irreversible damage to the machine. The purpose of any machine or equipment maintenance is to reduce or eliminate losses caused by applying an unsuitable production method or often also as a result of a human factor. However, maintenance is to take care of machines and equipment and plan the costs associated with equipment operation and manage the range and number of spare parts [1,2]. According to [3], it is a matter of ensuring that machines can produce products in the required quality and quantity, at the lowest possible cost and in the shortest possible time. The types and methods of maintenance by which these goals are met have undergone significant changes. From the first corrective maintenance, which means the maintenance performed after a machine failure, which began to be applied in the distant past, we have gradually moved on to preventive strategies as presented in this article in the case study.

As part of the predictive maintenance approaches using machine condition diagnostics and prediction are dominated and desired.

2 Predictive maintenance

Predictive maintenance (PdM) seeks to determine the right moment for maintenance based on advanced statistical methods and artificial intelligence [4-7]. Unlike preventive maintenance, the maintenance of each device is assessed and planned based on the current state of the device while using various models to reveal the time and date of the failure. Subsequently, it is possible to extend or shorten maintenance cycles according to the actual state of the device. A well-functioning predictive maintenance system is closely linked to a well-designed diagnostics and prediction system that uses advanced statistical methods and artificial intelligence. With the help of predictive maintenance, it is possible to optimise operating conditions, improve the quality of products and services and thus make the most of the investment [8-10].

Predictive maintenance is one of the maintenance strategies, which may be understood as a set of rules based on which the maintenance schedule is prepared and the performance of individual maintenance activities. Usually, several strategies are applied together on the machinery. The choice of an appropriate strategy depends on several factors: state of the machines, the possibilities of implementing the chosen strategy, or the economic advantage of prevention [3]. Three terms are known within the maintenance strategy - corrective, preventive, and predictive maintenance (Figure 1). Corrective maintenance is the oldest maintenance strategy performed after a machine failure and can be found in the literature as reactive maintenance. The purpose of corrective maintenance is to put the machine into operation immediately after failures in the shortest possible time and with the lowest losses [3,11].

To reduce the inefficiency of corrective maintenance, manufacturing companies have switched to a preventive maintenance model. Preventive maintenance works on the principle of planning regular service of machines, whether it is repaired, replacement of parts, oil change, lubrication, and so on. The aim is to prevent machine failures before they occur, which eliminates the possibility of unexpected production downtime. Preventive maintenance is currently the dominant company maintenance strategy, but it is still far from optimal because machines often fail at the end of their service life. Companies must create maintenance plan based on actual information about the asset's condition to achieve optimal maintenance activity and not only on theoretical considerations. Predictive maintenance means that companies can plan maintenance activities based on accurate predictions of the device's life [12].

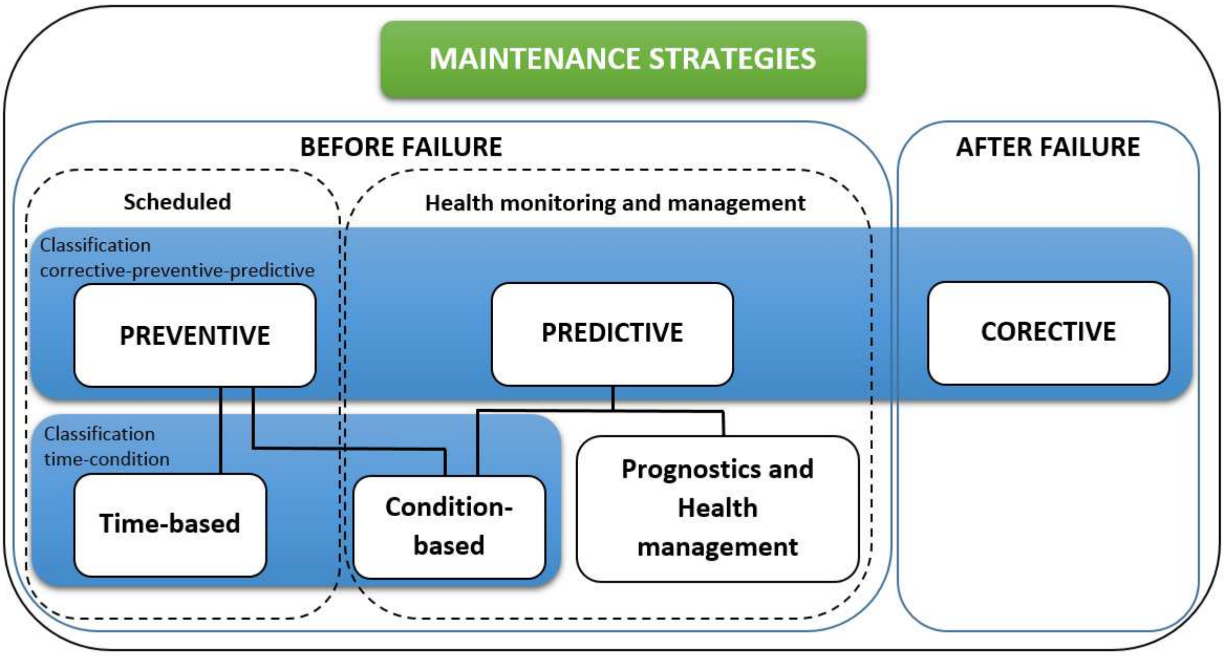

Figure 1 Maintenance strategy overview [11]

Predictive maintenance can solve the following problems: predict device failure in the future, identify unusual behaviour of the device, estimate the remaining life of the device, warn of incorrect setting of operating parameters [4]. Predictive maintenance thus brings innovations to the company, which improve the current maintenance system. For several years now, a set of OECD manuals has been used as a guide in science, research and innovation. The "Oslo Manual" [13] focuses on defining the concepts of innovation and innovation activity, and its definitions are currently used by 80 countries around the world. The Oslo manual defines an innovation as [13]: *"a new or improved product or process (or combination thereof) that differs significantly from the unit's previous products or processes and that has been made available to potential users (product) or brought into use by the unit (process)"*. This definition uses the generic term "unit" to describe the actor responsible for innovations (companies, households or associations).

The latest edition of the Oslo manual reduces the previous list-based definition of four types of innovations (product, process, organisational and marketing), to two main types: product innovations and business process innovations. Predictive maintenance is key to optimizing internal processes, boosting service levels and ultimately increasing customer satisfaction. The benefits that PdM brings can be classified as business process innovation, which are defined as [13]: *"a new or improved business process for one or more business functions that differs significantly from the firm's previous business processes and that has been brought into use by the firm"*. Business process innovation include: production, distribution and logistics, information and communication systems [13].

Although PdM is a fundamental pillar of the Fourth Industrial Revolution - PdM 4.0 [5,14,15], very few companies can still predict the future failure of machines with sufficient accuracy and immediately apply the most effective preventive measures to the detected deviation. In most companies, predictions are made without smart sensors and artificial intelligence. They use diagnostic tools for measurement (vibration, temperature, or oil quality) to create short-term predictions. Predictive maintenance is at different levels in different companies and this influence significantly logistics and manufacturing processes. The authors Mulders and Haarma describe four levels of the company's Predictive Maintenance Maturity Matrix (Figure 2). The individual levels are defined as follows [16,17]:

Level 1 – Visual inspections: periodic physical inspections. The conclusions are based solely on inspector's expertise.

Level 2 – Instrument inspections: include expanding technical expertise and instrument inspections at periodic intervals, which provide more specific and objective information about machines. The conclusions are based on a combination of the 'inspector's expertise and instrument read-outs.

Level 3 – Real-time condition monitoring: continuous real-time monitoring of assets, with alerts based on pre-established rules or critical levels. The machines are constantly monitored by sensors that provide up-to-date data representing the state of the machine.

Level 4 – Predictive maintenance 4.0: continuous real-time monitoring of assets, alerts sent based on predictive techniques, such as regression analysis. It is about predicting future machine failures and the immediate application of the most effective preventive measures.

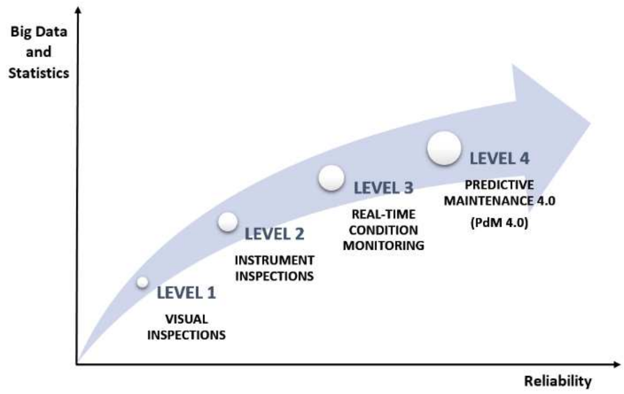

Figure 2 Predictive Maintenance Maturity Matrix [16]

When implementing predictive maintenance in the company, it is essential to know which individual types of failures can be identified from the available data and which parameters need to be collected. In the case of a large number of machines and devices in the company, it is not necessary to install sensors on all of them. First, it is required to focus on critical machines, the failure of which would directly affect production or stop it. Predictive maintenance research has a lot of attention in industry and academia due to its potential benefits in reliability, safety, and maintenance costs, among many other benefits. Predictive maintenance might [11]:

- reduce maintenance costs by 25%–35%,
- eliminate breakdowns by 70%–75%,
- reduce breakdown time by 35%–45%,
- and increase production from 25%–35%.

Predictive maintenance also requires less staffing of the maintenance department. Machine learning excels precisely in the tasks that consist of analysing a large amount of data. In practice, it is not realistic to accept a top expert for each machine, who will analyse hundreds of measurements a day. However, this is not a problem for artificial intelligence [4]. Despite the many benefits of PdM introduction, companies also have to deal with the risks during its implementation. The risks of PdM include [4]:

- *Early termination of the PdM project* – a longer time is needed to find hidden failures in the machine learning model.
- *It is impossible to predict the collected data* – at first, it is essential to analyse the types of failures (FMEA analysis) and then implement the Proof-of-Concept phase.
- *Overconfidence in the power of machine learning* - PdM cannot completely replace preventive

maintenance and diagnostics. However, it can reduce its need and extend inspection intervals.

- *Risk of later return on investment* - data scientists can wait weeks or even months for the data they need to analyse and make suitable predictive models.
- *Reprogram of machine learning models* - sometimes machine learning models need to be reprogrammed, which is more time consuming.
- *Missing professional employees* – not enough specialists and data scientists.

3 Methodology

Following the goal of the presented paper, we focused on increasing the PdM maturity matrix to a higher level in a selected industrial enterprise. The modified preventive maintenance model was used to identify the current state of the level of maturity and perform the analysis following the recommendations of the strategic document Manual for companies for the introduction of artificial intelligence [4]. The conducted model of preventive maintenance contains six steps for the implementation of predictive maintenance in the company: identification of critical equipment and its parts; identification of degradable mechanisms and key parameters; implementation of equipment monitoring, montage of detectors, data analysis and trend identification, evaluation of results/project. In addition to implementing these six measures, companies must also ensure that they comply with the following six predictive maintenance assumptions: People, Applications, Infrastructure, Process, Data, and Organisation. We would like to emphasise that the implementation process fails if the company plans predictive maintenance but does not have enough specialists with specific comprehensive knowledge about the equipment and the technology. It is also necessary for success of project to create an infrastructure for collecting the specific data for prediction analysis. This innovation might include a transformation of the whole organisation, its corporate culture and thinking towards change from "traditional" to "digital" maintenance. The described model of preventive maintenance is presented in Figure 3 below.

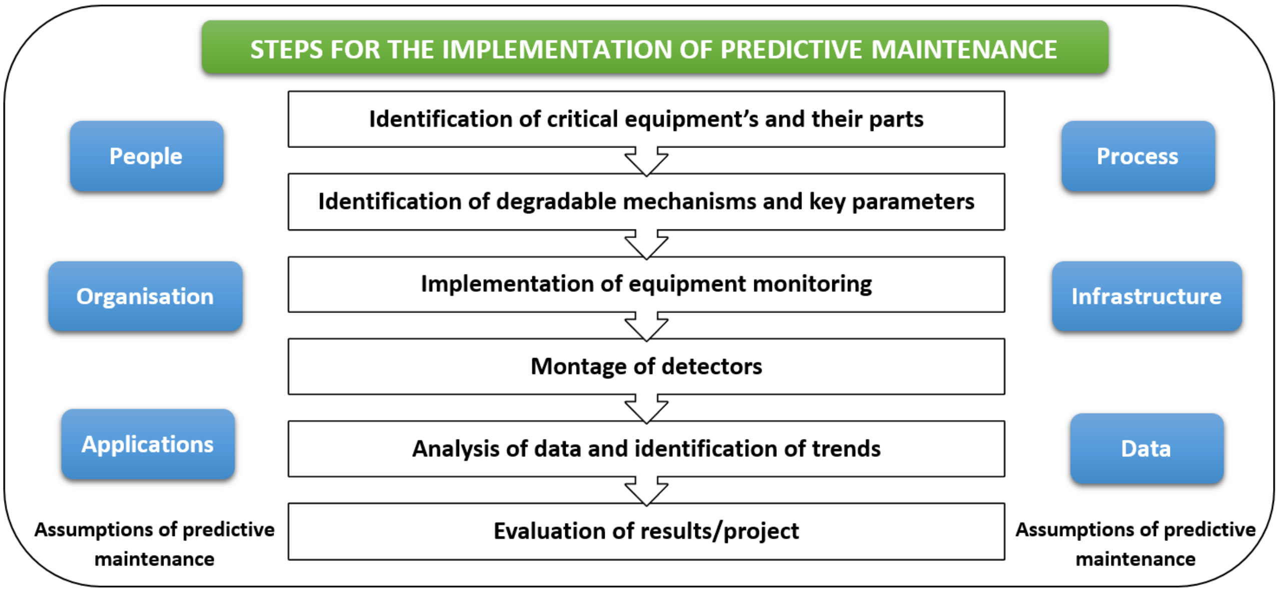

Figure 3 Modified model for implementation of predictive maintenance

The FMEA (Failure Mode and Effect Analysis) was used to identify the main causes of the failures. FMEA analysis was used to identify and assess the risk of potential mistakes, as well as their consequences [18-21]. Each threat was assessed according to its probability of occurrence (P), severity (S) and detection (D). The risk priority number (RPN) was calculated according to the formula

$$RPN = P \times S \times D \qquad (1)$$

Where [18]:

- P - probability coefficient, specifying the frequency of occurrence of the machine failure associated with a given risk, on a scale from one to ten, where one means no occurrence, and ten is for occurrence in each production cycle.
- S - severity coefficient, which determines how severe the given risk of the machine failure is, on a scale from one to ten, where one means negligible importance, and ten very high.
- D - detection coefficient, which determines the degree of difficulty in counteracting a given type of structural failure (early detection of the cause), is very difficult on a scale from one to ten, where one is an easy possibility to counteract, and ten is very difficult.

The risk priority number (RPN) may vary from one to 1000. The higher the RPN value is, the greater the risk associated with the threat is.

4 Results and discussion

This part of the paper focuses on applying the introduced modified model to implement predictive maintenance in the selected enterprise as a case study. The analysed industrial enterprise focuses on producing rubber-metal and plastic parts for the automotive industry, rail vehicles, ships, and aircraft. According to analysis, several types of maintenance are performed in the enterprise (autonomous, operative, preventive).

The technical diagnostics helps to avoid costly maintenance interventions, especially for critical machines. The enterprise has 354 machines and equipment, while technical diagnostics focuses on the following three areas: tribodiagnostics, thermodiagnostics and vibrodiagnostics.

- Tribodiagnostics is a method of diagnostics to detect, evaluate, and report foreign substances in the lubricant and its change from a quantitative and qualitative point of view. The oil level monitoring is performed on 130 machines in the analysed enterprise.
- Thermodiagnostics as a non-contact temperature measurement can be used wherever the diagnosed parameter is heat radiation. The aim of thermodiagnostics is to locate a possible problem on the machine caused by excessive overheating of its parts and to eliminate it in time. For measuring surface temperatures, such motors, heating coils and pumps are used by a handheld thermal imager. Thermodiagnostics determines whether the measured temperature exceeds the limit value (temperatures on the hydraulic circuit must not exceed 60 °C when the hydraulic oil loses its properties and degrades rapidly) or whether the measured temperature of the equipment during tempering does not deviate from reality. Another type of technical diagnostics that is performed in the enterprise on 120 machines is thermodiagnostics.
- The vibrodiagnostics aims at the smooth and reliable operation of the device. The service life of bearings can be affected by several factors, such as speed, dirt, working temperature, lubrication efficiency, bearing stress. Vibrodiagnostics locates the fault and determines the current state of the machine using a vibration sensor. It is non-disassembly diagnostics without the need to stop production. In the presented case study in the mentioned enterprise, there are 143 rotary machines on which vibrodiagnostics is performed. Competent employees who perform this type of technical diagnostics try to determine when the bearing is coming the end of its life.

The analysed enterprise is indicated on the second level PdM maturity matrix (Figure 2). Monitoring of the technical condition of machinery is performed at specified intervals, which are shortened and archived if necessary. Exceeded limit values are monitored. In the case of limit values, the evaluation is subjective, performed by technologists without sufficient theoretical knowledge about predictive maintenance and statistical data processing.

4.1 The procedure of introducing predictive maintenance on a production line in an industrial enterprise

The transition of an industrial enterprise to the third level of Predictive Maintenance Maturity Matrix requires real-time monitoring of machine condition, where sensors continuously collect data on the state of individual machines and equipment. Sensors send alerts based on predetermined rules or when critical levels are exceeded. According to the Manual for companies for introducing artificial intelligence [4], the introduction of Level 3 of the Predictive Maintenance Maturity Matrix was implemented online L in the following six steps.

1. *Identification of the critical equipment and its parts*

Simultaneously with the analysis, a simulation of predictive maintenance on a selected production line was carried out to identify problems and shortcomings that would not be revealed themselves. The selection of a specific production line was based on the ABC categorisation of machines as follows: Group A are strategic machines considered critical because a failure on the machines of this group causes partial or complete shutdown of production. Malfunctions on these machines result in high financial losses and the possible occurrence of a dangerous accident. Group B includes machinery with high priority, but in the case of failure, there will not be such severe consequences for the enterprise's production activity as for machines from the group A. The group C consists of other auxiliary devices that are not included in groups A and B. Based on the above classification of machines, machines from the group A have the highest priority, and it is essential to make predictions of possible failures. The mentioned group in the enterprise includes the production line with the working name Line L as the subject of the analysis. The L-line includes vulcanised parts for damping vibrations and vibrations in cars, the so-called silent blocks.

As already mentioned, the Line L belongs within the ABC categorisation among the equipment of the group A, the failure of which can cause a partial or complete shutdown of production. Based on the failure analysis (FMEA), two rivet heads in series were identified as critical for operating a given production line. The production and service of rivet heads are carried out exclusively in the country of the manufacturer, in the area outside the European Union. The logistical activities associated with the service take two weeks, and complications due to the customs procedure are several weeks longer. For this reason, it is essential to correctly predict the wear of the rivet heads, as their unexpected damage would cause undesirable production downtime.

2. *Identification of degradation mechanisms and key parameters*

First, the main parts of the rivet head were identified. The rivet head consists of the following functional elements: hydraulic, mechanical, pneumatic, and electrical. Based on FMEA analysis, critical parameters and degradation mechanisms were identified for individual components of the rivet head: the type of failure (error) that can occur on the component (equipment), the cause of the fault and the consequences of the fault. The FMEA analysis showed that all failures with the most significant impact on the functionality of the rivet head are indicated by an increased operating temperature, which is well measurable, distinguishable from the usual operating temperature. If the fault persists, the temperature usually rises. Early detection of disorders helps to prevent them easily because most disorders begin as an abnormality.

3. *Implementation of machine monitoring*

The implementation of condition monitoring for the critical equipment includes installing the necessary sensors, a system for collecting and storing this data and subsequent monitoring [16]. Based on the previous analysis and experience, it was found that the most failures on the rivet head are indicated before by an increase in operating temperature. For this reason, a temperature sensor was placed for condition monitoring.

4. *Installation of sensors*

In order to monitor the temperature of the machine, it was necessary to map the surface temperatures of the device during production. Surface temperatures were measured using a thermal camera applied in the enterprise for the thermodiagnostics. The highest temperatures were measured at the tip of the tool that forms the semi-finished product. A temperature sensor with a set alarm temperature of 60 °C, which is the upper limit of the operating temperature of the hydraulic oil, was then installed at the identified location. After several experiments, the sensing temperature period was set at ten minutes. The optimal time for measurement might be set so that the temperature is not sensed too often, causing an amount of unnecessary data, but sensing at long intervals is not recommended so as not to detect abnormalities in the operation of the rivet head.

5. *Data and trend analysis*

Data analysis is a necessary assumption for the correct implementation of predictive maintenance. A cloud application already provides the basic visualisation of data (temperatures over time). However, this data was exported to a spreadsheet processor Microsoft Excel to work with the measured data. The production was interrupted when it was necessary to wait for the parts to cool down after vulcanisation or a failure occurred and due to production interruption during the corona crisis (Figure 4a). Temperature values were excluded from the data set for further data analysis when the rivet heads were not in operation (Figure 4b). The next issue was the identification of the presumed temperature trends from the measured values. The values of the temperatures of the rivet heads during the production process are considerably fluctuating, and it is not easy to identify trends. The function of linear trendline in the Microsoft Excel program was used to indicate the possible trend of temperature values, ordering one-dimensional data in a straight line towards the future.

6. *Assuming the case study*

The assumed trend of the temperatures of both rivet heads indicates an increasing character of temperatures from the beginning of the measurement (Figure 5). The more reliable long-term prediction will require longer-term measurement and a more extensive data set. However, the presented procedure and scope of the conducted analysis, when diagnostic sensors were mounted on the rivet head, was sufficient for base recommendations to improve the level of Predictive Maintenance Maturity Matrix in an enterprise. A primary trend visualisation has been introduced into the enterprise, which is also well usable in processing scanned data in vibrodiagnostics and is easy to understand by workers responsible for technical diagnostics without special training. In this solution, the knowledge of employees trained at Six Sigma was used, representing a good base of statistical knowledge for future prediction needs. Implementing the *Manufacturing Execution Systems* (MES) system is planned to start in the enterprise.

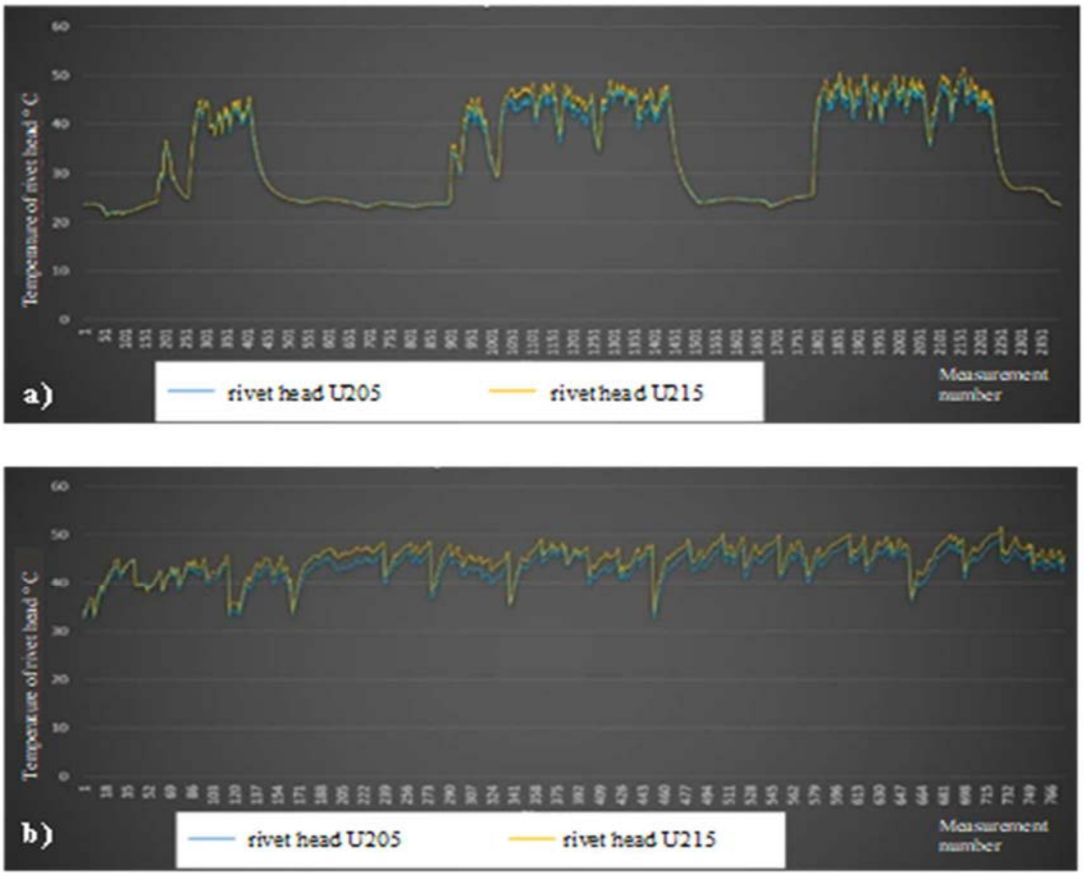

Figure 4 Temperature profile of rivet heads a) during production time and non-production time b) during production time

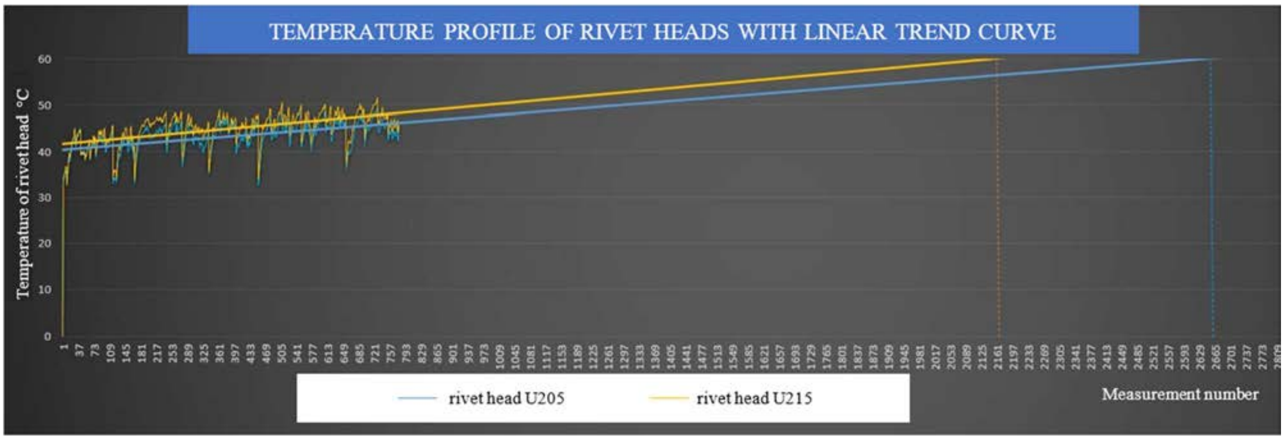

Figure 5 Temperature profile of rivet heads with linear trend curve

4.2 Prerequisites for improving the level of Predictive Maintenance Maturity Matrix in an industrial enterprise

The next part of the paper describes the key assumptions (Process, Infrastructure, Applications, Data, People and Organisation) that an industrial enterprise should analyse to improve the Predictive Maintenance Maturity Matrix [4]. The individual assumptions are closely related to the steps based on which the proposal to introduce predictive maintenance on Line L was implemented (Figure 3).

Process: The first prerequisite for the correct operation of predictive maintenance is familiarity with the whole process. The company should map its technology well, identify diagnostic methods on its equipment, know the types of failures and, above all, the causes, and conditions under which the failure occurs. A thorough analysis of the maintenance department was performed in the analysed enterprise. Machines were divided according to the ABC categorisation, and individual types of technical diagnostics were identified. Realised technical diagnostics were performed on the machines using specialised diagnostic devices.

It is necessary to perform a comprehensive analysis of machinery and equipment throughout the enterprise for the analysed industrial enterprise to move to the third level of Predictive Maintenance Maturity Matrix. Consideration should be given to the use of Predictive Maintenance 4.0 tools in terms of return on investment and safety and health, property, environment, or legislation under the supervision of an entity with experience in implementing such projects. The analysis must include identifying critical and less critical parts of the equipment, understanding their function, and identifying safe operating conditions. The FMEA method [21] is suitable for determining degradation mechanisms and their detection, which has also proved successful in the analysis of Line L.

Proper mapping of the whole process is a key part of the individual assumptions. If the company correctly identifies individual processes, it can determine which need to be optimised or transformed.

Data: If a company plans to predict, a collected data database is needed - measured values from sensors just before the fault and under different operating conditions. However, it is not necessary to focus only on the negative data that arises in the case of a failure. It is needed to have a sufficient database from a standard operation, during which the failure did not occur. Data collection must be preceded by a correct definition of the individual processes, so the data is collected only from devices on which predictive maintenance makes sense [4].

The analysed enterprise collects data unsystematically. The amount of collected data is not suitable for possible prediction, and at the same time, the data collection is realised in long time intervals. In this case, it is important to analyse current data [22] and select just those data on which the actual state of the equipment can be determined as accurately as possible.

Applications: For each plant, it is possible to assume different equipment for machines, and information systems may also be different for predictive maintenance, MES (Manufacturing Execution System), PLM (Product Lifecycle Management), ERP (Enterprise Resource Planning) will most often be used. An industrial enterprise can have all applications available or only selected applications, even from different manufacturers. Data collection systems such as MES., SCADA (Supervisory Control and Data Acquisition) are often enriched with additional data from ERP, CMMS (Computerized Maintenance Management System), EAM (Enterprise Asset Management) systems. Many EAM, CMMS systems today provide predictive maintenance as a package (from data collection to maintenance scheduling) [4].

For the analysis of the L-line, a freely available mobile application (EasyLog Cloud) for smartphones with the Android operating system was used. The application offers a basic overview table of the device, which ich named "Mote1". The application provides graphical processing of measured data. The visual output of the measured data (Figure 6) shows the course of temperatures on the rivet heads over time. The blue curve represents the measured temperature on the rivet head U205 and the red curve on the rivet head U215. The measured data were exported to Microsoft Excel spreadsheet.

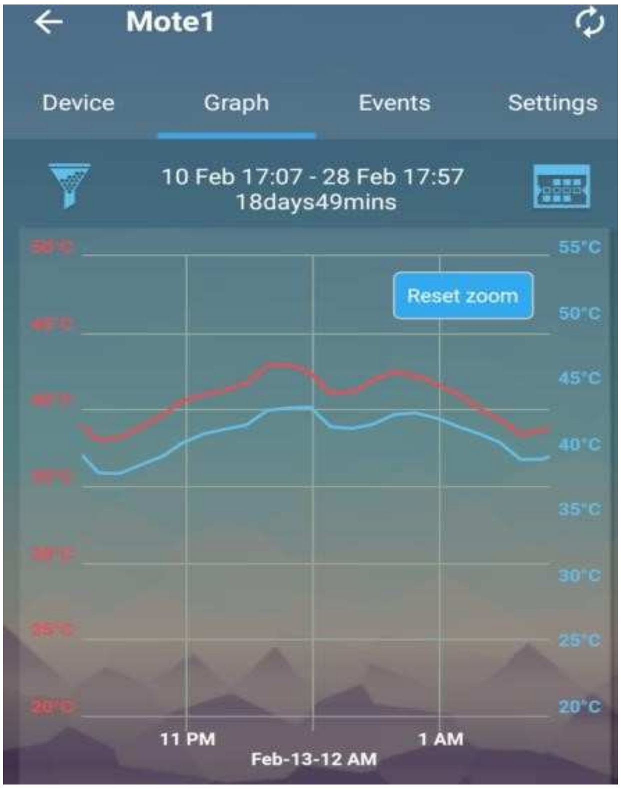

Figure 6 Display of measured operating temperatures of rivet heads over time

The selection of suitable applications for data collection, processing and display always depends on a specific enterprise, unique in its capabilities and current needs. However, the EasyLog Cloud application is used, and it is insufficient to implement enterprise-wide predictive maintenance. Currently, the analysed enterprise is working on introducing the MES approach [23], which is used to monitor production in real time. In this phase, the system is focused on production data from machines, which are then processed, evaluated, and visualised. According to the available information, the infrastructure is ready for data transmission for predictive maintenance.

Infrastructure: At present, traditional informational technologies (IT) in enterprises is replaced by cloud solutions, where the customer buys the service of a software solution and does not deal with the technical infrastructure on which this solution runs. As part of data transmission, basic processing, visualisation, and availability, the analysed enterprise was proposed to use the IoT sensor infrastructure (Figure 7), in which sensors mounted in machines send data directly to the cloud via a wireless Internet connection [24]. The main benefits when changing from traditional systems are the raise of flexibility, robustness, efficiency and also the chance for mastering the actual complexity [25].

The acquired data as part of logistics information flow can be monitored using a mobile application, and, if necessary, it can be exported to a corporate spreadsheet.

Figure 7 Diagram of IoT sensor infrastructure [24]

People: Although the gradual transition to predictive maintenance in the context of Industry 4.0 and Logistics 4.0 presupposes more maintenance staff, experts are required to analyse the moments in which artificial intelligence fails. According to Bronislav Balga [26], a specialist in business performance improvement, maintenance has been struggling for several years with the scarcity and quality of maintenance workers, which in recent years has shown very little or no progress towards Industry 4.0.

The analyzed enterprise has 41 employees in the maintenance department (from total of 850 employees). The main factor for implementing the proposed measures is the targeted training of maintenance department staff in prediction. Even under the influence of new modern technologies beyond the current understanding of predictive maintenance, the enterprise must continue to educate its employees. Predictive maintenance workers at Level 2 are experts in their field with extensive practical experience, but training in predictive maintenance is still necessary. Top employees should also understand the creation of predictions of failures and residual life of the equipment or its critical part. They should not passively rely on ready-made solutions provided by the technology supplier but also actively engage in improving predictions.

The enterprise must focus on improving the qualifications of employees in this area and, if necessary, cover some positions with representatives of third parties - external consultants. These are mainly professional functions, namely [4]:

- Data engineers who manage the data and the relevant data platform to make it fully functional for analysis;
- Data scientists who prepare, study, visualise, and model data on a data science platform;
- IT architects manage the basic infrastructure needed to support data science;
- Application developers deploy models to applications to create data-based products;
- Experts for data visualisation and interpretation.

Organisation: As in the presented case study, managers in the companies are often not fully aware of predictive maintenance benefits. The transition of an enterprise to predictive maintenance in the context of Industry 4.0 is more than just IT issue. It requires the transformation of the whole organisation, its corporate culture, which will change from "traditional" to "digital". It is a culture that prioritises employee engagement, stimulates experimentation with new technologies, and new ways of working. The culture will need to stimulate cross-functional cooperation and is comfortable with data-driven decision-making, even if decision-making goes against managerial and employee experiences and introduces a new way of thinking [10,27].

A prerequisite for successfully implementing maintenance using Industry 4.0 and Logistics 4.0 tools is support from the enterprise's top management, which will provide resources (finance, people, infrastructure, software, time, training) for its implementation, maintenance, and further development. When implementing the solution, it is appropriate to create expert working groups, within which there will be cooperation between maintenance technicians and data analysts who know the predictive model and its possibilities. The process of implementation requires a considerable amount of documented information [28,29]. In this step it is important to raise awareness of the various benefits of prediction across the enterprise [30,31].

5 Conclusions

Maintenance is necessary for the proper functioning of logistics in any industrial enterprise. Choosing the right strategy of maintenance can be saved a lot of work, time, and money. Predictive maintenance can manage maintenance more efficiently. Industry 4.0 and Logistics 4.0 concept opened a new horizon of possibilities using the most modern intelligent technologies streamlining maintenance in their company. Predictive maintenance is a key activator and impetus for Industry 4.0 and Logistics 4.0, while still facing several challenges in practical implementation from a technical and commercial point of view. Managers need to be aware of the main challenges to prepare for the digital transformation of production and the transition to the Industry 4.0 revolution.

The aim of this paper was to present and describe the steps and assumptions needed to improve the current state of the Predictive Maintenance Maturity Matrix in an industrial enterprise. Based on the analysis results, the enterprise can move to the third Level of PdM maturity matrix. Then following benefits will be achieved: reduced failure rates, reduced unplanned downtime and extended maintenance cycles, increased production, reduced spare parts, extended equipment life, increasing safety and reducing maintenance costs. Quality improvement in predictive maintenance will influence positive return on investment in approximately 3-5 years. Several studies confirm that predictive maintenance management benefits overall operations in both manufacturing and process plants [32]. However, with all the benefits of predictive maintenance, the risks and obstacles to its implementation should not be forgotten [33]. The real challenge is not in sensor technology, data processing, condition monitoring or correct diagnostics. These solutions are highly advanced and their implementation requires extensive knowledge and understanding. Thus, the implementation of contemporary solutions in the field of Industry 4.0 and Logistics 4.0 requires that the organization first improve the absorption of knowledge [34]. This concept, introducing revolutionary changes in manufacturing and logistics, will fundamentally change society and economy [35]. Businesses now need to focus on the predictive skills of their employees and support processes and opportunities that will support the creation of a new predictive-oriented business model.

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AN EMPIRICAL COMPARISON OF DRP AND DEMAND-DRIVEN DRP

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Keywords: supply chain, distribution networks, Distribution Resource Planning, Demand Driven Distribution Resource Planning, demand variability.

Abstract: Companies are nowadays challenged to offer high service levels while minimising inventory costs in an ever-increasing competitive market. One of the keys is to manage and improve the product flow in the distribution network continuously. In this paper, Demand Driven Distribution Resource Planning (DDDRP) is a proposed model for product flow management in distribution networks. It allows to optimise the flow by managing customer demand fluctuations. A literature review about flow management policies is presented, and then a case study is provided to make a comparison of the DDDRP concept with conventional management methods such as Distribution Resource Planning (DRP). To achieve this comparison, a discrete event simulation (DES) is adopted to measure the effectiveness of each model regarding the demand fluctuations, using key performance indicators. The simulation gives empirical results and illustrates the interests and benefits of the DDDRP approach in terms of inventory costs and service levels. The originality of this document concerns the assessment of Demand-Driven Distribution as a new approach of management and opens up new opportunities for optimising inventory and product flow in distribution networks.

1 Introduction

Companies are now required to appropriately manage products and information flows through supply chain distribution networks. As a definition, flow management entails coordinating all of the operations carried out during the product's distribution. It is critical since it directly influences inventory levels in each distribution unit and, consequently, the overall working capital and service levels. Bad flow management can result in a discrepancy between the quantity sold to the buyer and the amount produced by the manufacturer [1]. Many authors declare that optimising flow must take into account the important factor of demand variability management [2-4].

In this regard, Distribution Resource Planning (DRP) is a well-known push system that uses demand forecasting to determine when and how much the product should be replenished in downstream sites [5,6]. Moreover, pull systems have been developed as part of concepts such as LEAN, Theory of Constraints, and Just-In-Time. They offer real-time ways to deliver the product after the justification of the consumer demand [7,8].

On the other hand, Demand Driven Distribution Resource Planning (DDDRP) is a concept that combines the best of both systems by putting buffers in strategic points of the distribution network and pulling flow between them. Thus, it integrates the main axes, which are Lean distribution [7], Theory of constraints [9], and DRP logic [10].

The literature dedicated to evaluating the efficiency of flow is scarce. However, it has been proven that a good flow must contribute to a good service rate and an optimal inventory cost [11].

In this article, the efficiency of adopting a demand-driven strategy in distribution networks is evaluated by using an empirical analysis based on a real industrial situation. For this, we simulate the models through a multitude of demand variability scenarios and examine the effects on inventory and service levels.

The paper starts with a literature review on flow management models, describing the differences between the pull and push-flow approaches. Secondly, we give DDDRP model drivers, steps and formulas. The case study details and model implementation are then presented. Finally, we analyse the scenarios and the results of the simulation.

This paper is one of the first contributions to offer a new perspective on distribution management based on real consumer demands. We structured the work by proposing the axes, describing the model, and testing it empirically.

2 Flow management models: literature review

2.1 Push flow models in distribution

A push flow system is a strategy that involves pushing products through distribution networks in order to build up an inventory that can meet customer demand. Since 1970, Distribution Resources Planning (DRP) has been used to control inventory in a multiproduct, multi-echelon physical distribution environment. Since its appearance, the implementations of the DRP paradigm in distribution systems have reported several benefits. DRP is based on demand forecasting and replenishment generation, and it determines the time and quantities of all downstream

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replenishments. It was first proposed as an extension to Material Requirement Planning (MRP), moving the same logic from production to distribution. To perform a DRP grid, inputs data include sales forecasts, customer orders, available inventory and stock security policy. Then, DRP method gives a calculation of resource requirements related to the quantity of needed products, time, transport and stock investment needs [6]. Many recent works studied the implementation of DRP model in various industrial sectors. In fact, some researchers focus on finding the best lotting techniques for the distributed items using the DRP method [12]. A study uses DRP technique to determine the appropriate quantity and replenishment time in inventory decisions in the food industry [13]. Otherwise, the autoregressive integrated moving average (ARIMA) model has been used since the DRP requires precise forecast data [14]. This study concerned a company of mining and trade of oil and gas. Some works try to find the best forecasting approach based on the time series of each Distribution Centre (DC) using the DRP method to avoid inventory shortage problems [15]. Moreover, based on the case of the oil fuels industry, some authors studied the need for diesel oil for companies using DRP approach [16].

2.2 Pull flow models in distribution

2.2.1 Lean distribution

To reduce waste and boost productivity, Lean principles can be applied to any distribution function [17]. Lean distribution is defined as a technique that replaces traditional ways focused on inventory and rescheduling to cope with the changing customer demand. It has recently gotten considerable attention from academics and industries. It focuses on avoiding waste in the downstream supply chain with the goal of putting the right product in the right place. In other words, it presents the ability to sustain a high level of customer service by reducing waste and movements in distribution centres [18].

Well-known companies such as Wall Mart, Tesco, and IKEA have all employed lean distribution. They adhere to a philosophy of adapting inventory movement to customer demand in order to improve operational product flows and respond quickly to demand changes from the supplier to the sales location [7].

There is much evidence in the literature about the economic benefits of implementing Lean distribution. In fact, they are related to the decrease of finished items stock, as well as shortening delivery lead times and change-over times [19]. Table 1 summarises the differences between traditional distribution management and lean distribution. Similarly, based on a case study in a Serbian company, table 2 shows some quantitative benefits of implementing lean concepts in distribution units.

Table 1 Comparison between Lean distribution and traditional management tools

Distribution elements	Traditional distribution management	Lean distribution
Systems variations	**Variations cause continuous resetting for plans**	**Isolation of variations and take them in consideration in all lean practices**
Forecasts	**The constraint of being more accurate in long-term and short-term planning**	**Used only for long-term and aggregate planning**
Inventory	**The inventory should not be close to customer orders**	**The inventory should be close to the source and redirected according to the replenishment needs**
Transportations	**It is forecast-driven**	**It is demand-driven and takes in consideration delivery conditions**

Table 2 Quantified improvements after LEAN distribution implementation [20]

Area of improvement	Improvement quantity	
	Before	After
Inventory accuracy	**9.29%**	**5.97%**
Reducing lost-time accidents	**15-20 days**	**7-10 days**
Reducing picking error	**0.17%**	**0.01%**
Inventory levels	**Decrease of 76%**	
Required storage space	**Decrease of 51%**	
Warehouse productivity	**Improvement of 9.43%**	
Warehouse productivity	**Improvement by 5%**	

Tables 1 and 2 demonstrate the relevance of implementing Lean techniques in distribution contexts. They show that the management does not rely on forecasts but actual customer demand, except for long-term and aggregate planning.

2.2.2 Theory of Constraints

The Theory of Constraints (TOC) offers a wide range of applications, including reducing material flow costs throughout the supply chain [21]. It provides a demand-pull approach, as opposed to typical replenishment models, which result in inventory accumulation and/or shortages, and eventually an inability to meet customer demand [22]. The core concept of TOC is that every firm can have a constraint that should be used to improve the system's performance [10]. Constraints are described as an element that prevents a system from fulfilling its intended objectives. The weakest link in an organisation appears to be the source of problems, which is physical in the form of bottleneck resource, with a capacity that is less than or equal to the demand imposed on it [23].

TOC is used in various industries, including production, finance, project management, marketing, supply chains, management, and commerce, with distribution being one of them. In reality, TOC allows for a shift in the distribution network from a push to a pull model, with goods being delivered according to market demand.

The use of TOC in distribution systems attempts to reduce inventory investment, lead time, and transportation costs while also improving customer service levels.

Multiple evidence are stated in the literature about implementing TOC in distribution, such as GM's Cadillac Division's aborted introduction of Custom Xpress delivery (CXD). P&G's reported an inventory reduction of US$600 million, and makers of Crayola crayons' reported improvements in customer service levels and inventory reduction [5]. Authors in recent works used processing tools of TOC to focus on transportation constraints in the supply chain [24], while others contributed to transforming management systems in warehouses using TOC [25]. The application of TOC tools in distribution elements such as inventory, supplier liability and planning of sales is also discussed and evaluated [10].

We conclude from the literature that DRP, Lean, and TOC are pure push and pull flow systems in distribution. However, demand-driven distribution resource planning (DDDRP) has recently emerged, using all these principles. It relies on real demand and implements buffer at strategic places in the network, drawing flow from market demand to feed those Buffers. In DDDRP concept, Buffers are sized in a way to protect the flow from the consequences of demand fluctuations.

3 Concept of demand-driven distribution

3.1 Model drivers

Demand Driven DRP is a multi-echelon inventory planning and execution system for effective distribution network flow management. The purpose of the concept is to reduce variability propagating in distribution networks – due to demand fluctuations - by strategically placing Buffers. These buffers are separated into three continuously sized zones (Figure 1): Red (300 units), which is responsible for the safety stock. Yellow (500 units), which is responsible for demand coverage, and Green (250 units), which is responsible for determining the frequency and number of orders.

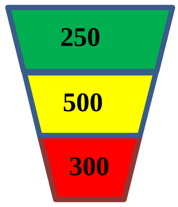

Figure 1 Sized Buffer

The Buffer zones are sized using a set of parameters and equations based on the DDMRP technique (equations 1 to 5) [26]. The concept of buffering, which is inspired by Lean distribution and TOC techniques, provides a solution to the amplification of variability in complex networks, which is often prone to cause inventory problems at network locations, either in the form of 'too little' causing miss sales and lack of components, or 'too much' resulting in excess cash and more needed space for stocking, known as the Bimodal effect (Figure 2).

To avoid the 'too much' or 'too little' issues, the target is to have the most of articles in an optimal range of inventory at all times (Figure 3) [26].

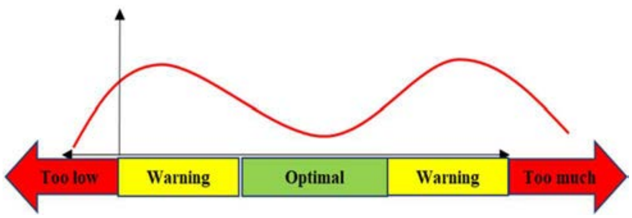

Figure 2 Bimodal effect

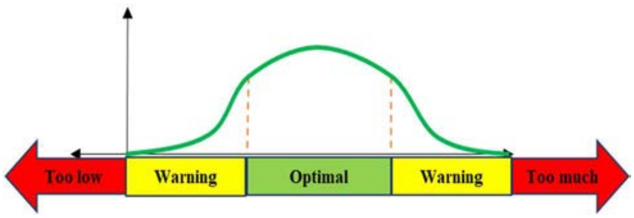

Figure 3 Optimal Situation of inventory

3.2 Parameters, steps and formulas

The Demand Driven DRP model is grouped into five parts, starting with buffer placement and ending with material replenishment execution. Figure 4 depicts a buffered random distribution network. Being physically in the form of decoupling 'hubs', Buffers are essential for reducing lead times and preventing amplified variability in the network. Due to the decoupling of 'Hubs,' the planning horizons will be shortened (Figure 4).

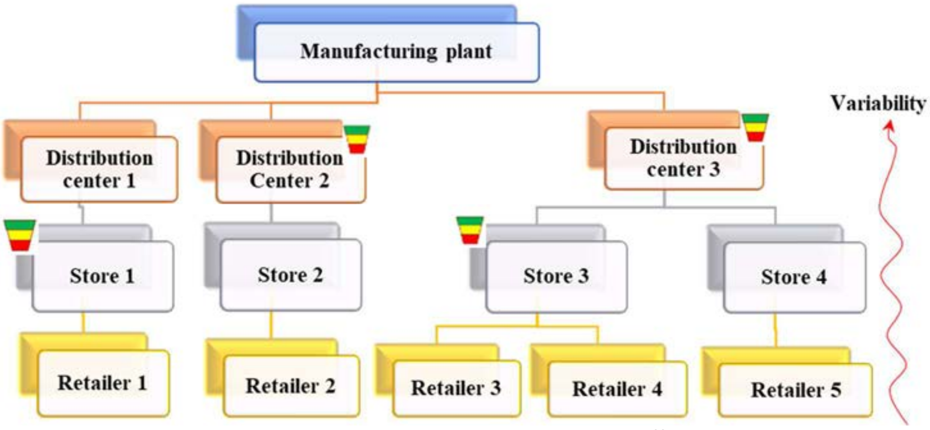

Figure 4 Distribution network with Buffers

After Buffer placement in the network, Profile and Sizes (step 2) refers to specific calculating methods; each buffer is colour-coded (figure 1). The buffer levels are determined using the distribution parameters, which include the lead time (LT) from a supplier centre to a receiver centre. In the context of distribution, LT refers to the time it takes to launch a product, prepare an order, load, transit, unload, and stock it. Otherwise, the longest cumulative non-buffered sequence in the distribution network is used to estimate decoupling lead time (DLT) for each reference. Buffer profile assignments are also included in the calculations (related to variability and lead time assignments). Furthermore, the calculation takes into account the average daily usage (ADU), product selling price, and demand adjustment parameters (DAF). The buffer profile and levels exploit the following DDMRP equations (1 to 5).

$$Red\ Base = ADU \times DLT \times lead\ time\ factor \quad (1)$$

$$Red\ Safety = Red\ base \times variability\ factor \quad (2)$$

$$Total\ red\ zone = Red\ Base + Red\ Safety \quad (3)$$

$$Yellow\ Zone = ADU \times DLT \quad (4)$$

$$Green\ Zone = ADU \times DLT \times Lead\ Time\ factor \quad (5)$$

The classic DRP incorporates the safety stock in a static way, allowing for the generation of a supply or replenishment order once the safety stock is surpassed. However, Demand Driven DRP, on the other hand, considers market changes as well as fluctuations in operating factors such as ADU to adjust Buffers continually. This variable character ensures a dynamic adjustment for the buffer (step 3), in which the level of protection flexes up and down depending on the condition of those parameters, implying that the buffer situation is constantly updated.

The level of adjustment prepares for the supply order generation phase (Step 4). The position of the net flow (NFP) in the buffer in relation to each article is crucial for generating those orders. The net flow equation is used to calculate this position, which takes into account Qualified sales (not forecasted sales), On-Hand Quantity, and Open Supply Quantity (equation 6). Based on the priority of every article, the last phase (step 5) is to execute or not the planned orders.

$$OH + OS - QS = net\ flow\ position \quad (6)$$

OH: On Hand Quantity, considering the available physical stock.

OS: Open Supply Quantity, considering the ordered but not received stock.

QS: Qualified Sales, considering Sales orders past due, sales orders due today, and qualified spikes.

3.3 Proposed Approach for DDDRP validation

For the study, a case of a three echelon network is proposed, with all relevant data valid, including distribution network, historical customer demand, lead times, initial inventory situations, and Holding/Manufacturing costs.

To perform this research, ARENA SIMULATION SOFTWARE was used to create a discrete event simulation (DES). With a replication length of one year, we can reproduce one year of distribution on a daily basis. The simulation will help to compare DRP and DDDRP models, by which we perform some relevant performance measures. They are working capital (WC) and on-time shipping (OTS) rates, which represent respectively inventory cost and service levels. Furthermore, simulation provides additional precise indicators for the models under consideration, such as the level of safety stock and Buffer sizes. Several different demand scenarios are studied in order to provide dependable and consistent results.

This approach was used on the DDDRP and DRP models in order to conduct an empirical comparison between forecasted and demand-driven concepts, as well as syntheses on each model's strengths and drawbacks.

4 Empirical study

4.1 *Case Study data*

A distribution network of a Moroccan structure specialising in the dairy products industry is the subject of the case study. Urban Distribution Centers (UDC), Regional Distribution Centers (RDC), and Factory are the three echelons of the distribution network (Figure 5).

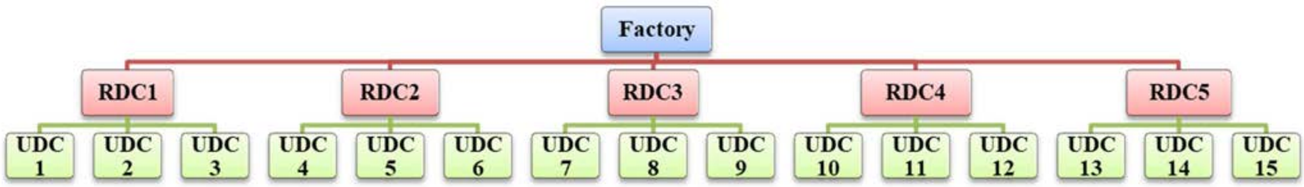

Figure 5 Distribution network of the case study

To conduct the study, the input parameters for all the UDCs and RDCs are initial On hand inventory, forecasted average daily usage (ADU) for every buffered location, and the Decoupling Lead time (DLT). Furthermore, the lead time (LT) (from RDCs to UDCs is 3 days, as is the Lead Time from Factory to RDCs), inventory holding costs, and selling prices are all provided.

Table 3 Some input data for three UDCs

Distribution Unit	Initial On Hand inventory	ADU	LT factor	Variability Factor
UDC1	**2000**	**400**	**50%**	**20%**
UDC2	**15000**	**3100**	**50%**	**20%**
UDC3	**15000**	**3500**	**50%**	**20%**

Table 3 shows an example of input data for the first three UDCs. ADU refers to the first month. Moreover, the duration of the LT and the amount of the demand variability are used to establish LT and variability factors.

4.2 *Models' implementation*

4.2.1 DRP implementation

Every UDC builds a DRP grid based on forecasted demand that is developed locally. Then it communicates the replenishment orders to the RDC supplier, which elaborates in the same way as its own DRP grid. In addition, every location takes into account its unique security requirements. Table 4 shows an elaborated DRP for UDC1 during the first 10 days of the year, with variable forecasted demand.

Table 4 Elaborated DRP for UDC1

Security stock	**550**		Week	1	2	3	4	5	6	7	8	9	10
			Demand	**550**	**550**	**550**	**550**	**550**	**2200**	**2200**	**550**	**550**	**550**
On Hand Start	**8000**		End Inventory	**8000**	**7450**	**6900**	**6350**	**5800**	**5250**	**3050**	**850**	**2300**	**1750**
Supply Quantity	**2000**		Projected On-Hand	**8000**	**7450**	**6900**	**6350**	**5800**	**5250**	**3050**	**2850**	**2300**	**1750**
Lead time (days)	**3**		Schedule Receipt	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**2000**	**0**	**0**
			Schedule Start	**0**	**0**	**0**	**0**	**2000**	**0**	**0**	**2000**	**0**	**2000**

After the elaboration of DRP grids, the final push decision of the flow concerns the timing and quantity of all downstream locations' replenishments.

4.2.2 DDDRP implementation

The choice of strategic Buffer Positioning is referred in the Demand Driven DRP implementation to the 'Hub and Spoke' Configuration [26], which consists of installing an 'Inventory Hub' in the source unit and small stock locations on the warehouses (Figure 6). Consequently, all of our UDCs and RDCs are buffered in the case study. RDCs are thought to have sufficient capacity to meet the demands of UDCs. Table 5 depicts the second step of buffer sizing, showing a portion of the first month's findings for all UDCs units.

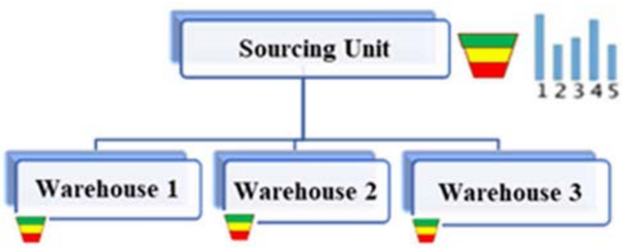

Figure 6 Hub and Spoke configuration

These calculated Buffer levels serve as the basis for the demand-driven planning process (Table 6). The real customer demand is represented in column 1, and future spikes are checked for a three-day horizon. Following that, the daily net flow position (NFP) in the buffer is stated in order to determine the order amount that has to be supplied.

The request day is the anticipated arrival date of the order amount. The NFP position in relation to the buffer sizes is shown in the planning priority. A supply is planned if the position is below the Top of Yellow (TOY), and the order amount is Top of Green (TOG) minus the NFP.

Table 5 Buffer sizing

		UDCs														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Parameters	ADU	400	3100	3500	600	1200	1000	1000	2300	3500	800	3200	2400	2100	1200	2400
	DLT	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	Variability Factor	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%
	LT Factor	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%
Buffer Levels	Red Safety	960	7440	8400	1440	2880	2400	2400	5520	8400	1920	7680	5760	5040	2880	5760
	Red Security	9	74	84	14	28	24	24	55	84	19	76	57	50	28	57
	Yellow zone	1200	9300	10500	1800	3600	3000	3000	6900	10500	2400	9600	7200	6300	3600	7200
	Green zone	960	7440	8400	1440	2880	2400	2400	5520	8400	1920	7680	5760	5040	2880	5760

Table 6 Demand Driven Planning

Day	Sales Order Due Today	Total Future Spike	On-Hand	On-Order	Showing-Up Order	Qualified Demand	NFP	Order amount	Request Date	Planning Priority
1	34604	16749	80000	0	0	51353	28647	23461	4	54.98%
2	0	16749	45396	23461	0	16749	52108	0	-	100.00%
3	16749	0	45396	23461	0	16749	52108	0	-	100.00%
4	13029	0	28647	23461	23461	13029	39079	13029	7	75.00%
5	0	0	39079	13029	0	0	52108	0	-	100.00%
6	0	0	39079	13029	0	0	52108	0	-	100.00%
7	913	21648	39079	13029	13029	22561	29547	22561	10	56.70%
8	0	21648	51195	22561	0	21648	52108	0	-	100.00%
9	0	21648	51195	22561	0	21648	52108	0	-	100.00%
10	21648	0	51195	22561	22561	21648	52108	0	-	100.00%
11	9535	0	52108	0	0	9535	42573	0	-	81.70%
12	764	0	42573	0	0	764	41809	0	-	80.24%
13	0	0	41809	0	0	0	41809	0	-	80.24%
14	5581	14838	41809	0	0	20419	21390	30718	17	41.05%
15	0	14838	36228	30718	0	14838	52108	0	-	100.00%
16	0	14838	36228	30718	0	14838	52108	0	-	100.00%
17	14838	0	36228	30718	30718	14838	52108	0	-	100.00%
18	10815	0	52108	0	0	10815	41293	0	-	79.25%
19	3666	0	41293	0	0	3666	37627	14481	22	72.21%
20	776	0	37627	14481	0	776	51332	0	-	98.51%
21	5566	0	36851	14481	0	5566	45766	0	-	87.83%
22	0	23301	31285	14481	14481	23301	22465	29643	25	43.11%
23	0	23301	45766	29643	0	23301	52108	0	-	100.00%
24	1133	23301	45766	29643	0	24434	50975	0	-	97.83%
25	23301	0	44633	29643	29643	23301	50975	0	-	97.83%
26	0	18096	50975	0	0	18096	32879	19229	29	63.10%
27	12189	18096	50975	19229	0	30285	39919	0	-	76.61%
28	0	41036	38786	19229	0	41036	16979	35129	31	32.58%

The final stage is to execute the planned orders. It is based on the Buffer status, which is calculated by dividing the On-Hand Status by the Top of the red zone (TOR). It allows making a decision about when to execute the detailed planning elaborated in the previous phase. The item with the smallest status creates an execution emergency. We didn't give much interest to this section because we were just interested in one product flow.

4.3 Models' comparison

4.3.1 Scenarios of Simulation

This study proceeds to challenge the Demand Driven DRP under several demand scenarios and compare it with a traditional DRP concept. The method entails employing three circumstances, which are listed in table 7.

Table 7 Scenarios of the simulation

Scenario	Particularity
1	**Stable demand along 12 months.**
2	**Variable demand characterised with 2 spikes every week. Each spike is 5 time the ordinary demand (Figure 7).**
3	**Monthly Seasonality, and the demand is fix along one month (Figure 8).**

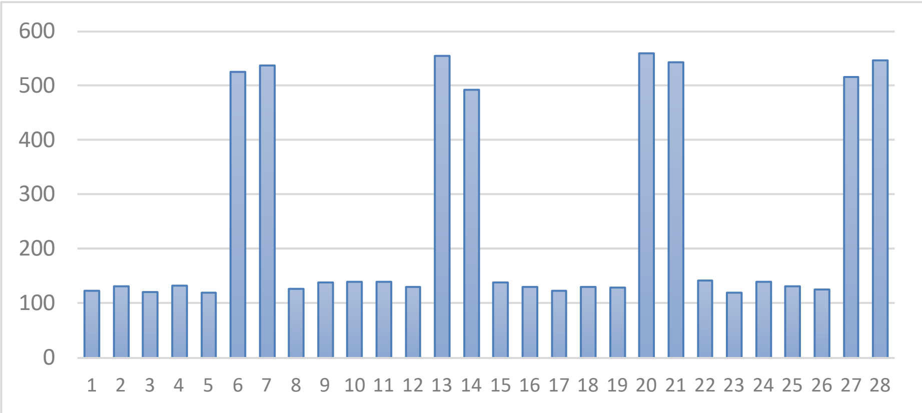

Figure 7 Demand with spikes

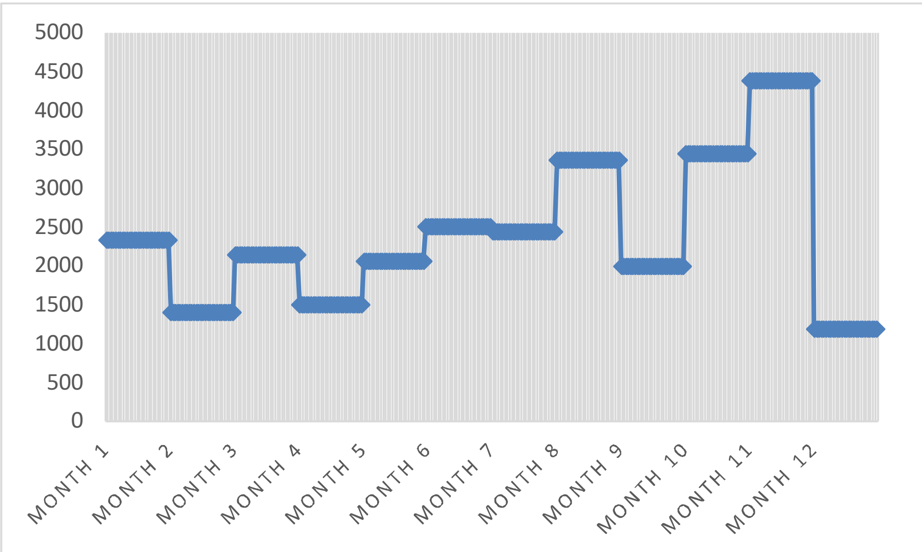

Figure 8 Seasonal demand

4.3.2 Results of simulation

Good flow management leads certainly to the minimum inventory cost and the best service level. That is why we generated key performance indicators (KPI) for service and inventory levels with ARENA SOFTWARE. We considered the same amount of annual demand in the three scenarios. The total amount of inventory cost represents working Capital during the simulated year, and the On-time Shipping rate is calculated by dividing the delivered on-time orders by the total number of orders. Table 8 summarises the findings for all the situations examined while using a deterministic lead time.

Table 8 ARENA Simulation Results

Scenario	Stable				Seasonal				Spikes			
Model	DRP		DDDRP		DRP		DDDRP		DRP		DDDRP	
KPI	WC (DH)	OTS	WC	OTS	WC	OTS	WC	OTS	WC	OTS	WC	OTS
RDC1	**5437.7**	**99.53%**	**1173**	**100%**	**7594**	**99.02%**	**1702**	**89.77%**	**5126**	**95.59%**	**2393**	**96.37%**
UDC1												
UDC2	**1637.54**		**1302**		**1483.46**		**1615**		**1895**		**3278**	
UDC3												
RDC2	**3324**	**98.25%**	**346**	**100%**	**3505**	**91.58%**	**1143**	**90.00%**	**3574**	**100.00%**	**1619**	**95.38%**
UDC4												
UDC5	**1389.72**		**551**		**1075.91**		**1125**		**954**		**1581**	
UDC6												
RDC3	**5375.2**	**100.00%**	**1064**	**100%**	**7897**	**92.28%**	**1612**	**97.69%**	**5276**	**99.30%**	**2919**	**97.03%**
UDC7												
UDC8	**2258.05**		**1319**		**808.18**		**1940**		**1556**		**2879**	
UDC9												
RDC4	**5329.2**	**100.00%**	**978**	**100%**	**5091**	**85.61%**	**2720**	**91.75%**	**5861**	**94.39%**	**3439**	**94.72%**
UDC10												
UDC11	**1963.59**		**1234**		**694.23**		**2486**		**1478.44**		**3323**	
UDC12												
RDC5	**4939.9**	**100.00%**	**882**	**100%**	**5416**	**99.30%**	**2006**	**97.36%**	**4321**	**100.00%**	**2296**	**99.01%**
UDC13												
UDC14	**2180.49**		**1153**		**1583.93**		**2015**		**1427.33**		**2681**	
UDC15												
Total KPI	**33835.39**	**99.56%**	**10002**	**100%**	**35148.71**	**93.56%**	**18364**	**93.31%**	**31468.77**	**97.86%**	**26408**	**96.50%**

The results in the table above are represented in the graphics in figure 9 and figure 10.

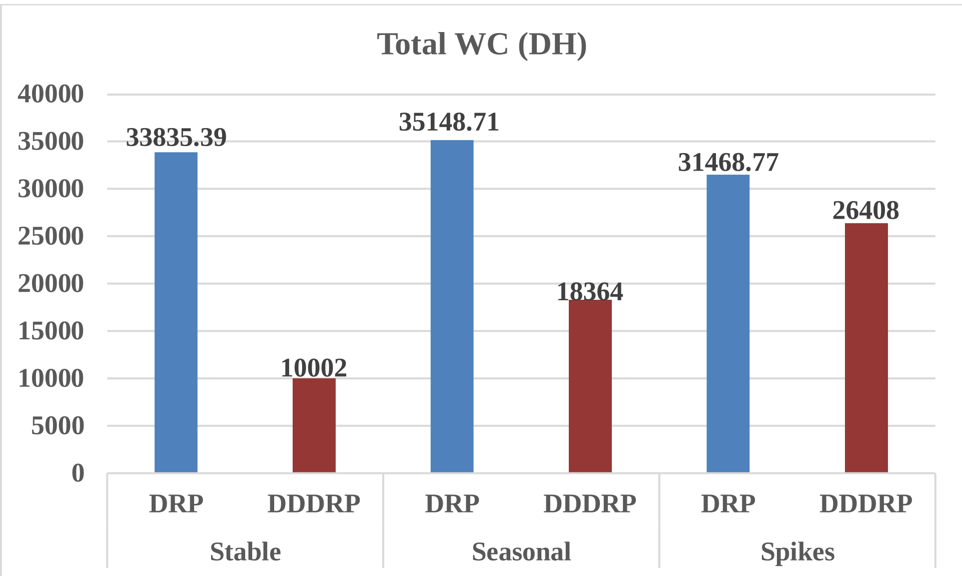

Figure 9 WC comparison between DRP and DDDRP models

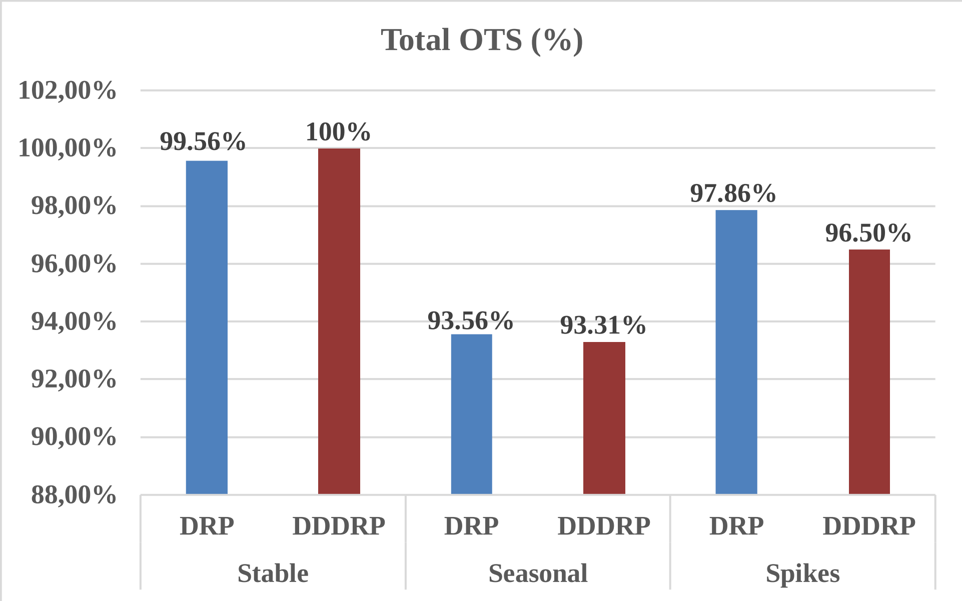

Figure 10 OTS comparison between DRP and DDDRP models

4.3.3 Interpretations and discussion

Table 8, figure 9, and figure 10 show the consumed inventory capital in each distribution unit and The OTS indicator that has been done for every three UDCs with their supplier RDC separately.

Both models present an ideal OTS for stable demand, but the significant difference is in the amount of stock required to ensure this rate. The DRP model's safety stock remains constant throughout the year. Aside from that, the DDDRP model's factors (LT factor = 0.5, variability factor = 0.2) represent the low degree of variability and the three-day of the LT. In terms of Working Capital, the end outcome demonstrates the advantage of demand-driven distribution.

On the other hand, the seasonal element has slightly altered the results. In fact, both models had a rise in inventory levels. It is valued at 4% for the DRP model and 83% for the DDDRP model. Concerning the DDDRP model, the LT factor remained unchanged, but the variability factor must be increased to accommodate demand fluctuations from month to month. As regards DRP, the safety stock policy remains unchanged, but the DDDRP buffer levels are adjusted monthly.

For the third scenario, inventory levels are reduced for DRP and augmented for DDDRP under the variable demand scenario (Spikes). These fluctuations are due to the imprecise estimation of LT and variability factors. The high level of precision used for forecasted demand also contributed to the stability of DRP inventory levels.

To summarise, the DDDRP model has the highest increasing amount of WC when demand shifts from stable to variable and seasonal. However, DDDRP outperforms DRP in terms of required WC to maintain an acceptable service rate in all circumstances.

5 Conclusion

The assessment of DDDRP model and the comparison of flow management policies in distribution networks are the main topics of this article. The purpose is to test how efficient these models are in terms of inventory and service levels under three different demand scenarios. A case study was used to compare the traditional DRP with the DDDRP technique. To accomplish so, a model based on real demand (Demand Driven DRP) was designed, with theoretical aspects described and procedures for implementation specified. Furthermore, for each model, a discrete event simulation revealed significant outcomes. In fact, demand driven DRP had high responsiveness to demand variability. Moreover, conventional DRP necessitates high forecasting accuracy. Finally, WC level in DDDRP is always higher than in DRP. The DDDRP model has demonstrated – at the first point – its benefits in this work. However, it can be challenging at certain levels of modelling.

In reality, the chosen LT and variability factors are critical, as they determine the Buffer levels and, consequently, the overall inventory level. So, works should be performed using heuristics to find the best factors choice in this situation. Otherwise, the study used a buffering approach which consists of putting a buffer in all the echelon's components (UDCs and RDCs). The optimal choice of strategic points for setting up buffers remains a challenge, especially for distribution networks with more than three levels.

As a perspective, the study of the process variability could consider a stochastic processing time in order to lead to more optimality in DDDRP policy.

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SUPPLY CHAIN PERFORMANCE EVALUATION MODELS: A LITERATURE REVIEW

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Abstract: Our structured literature review reveals the current state-of-the-art supply chain performance evaluation models (SCPEMs) from the last 21 years of research. Seventy related papers from the 2000 to 2021 time period were found to contribute by using ISI and SCOPUS databases. This paper has classified SCPEMs in terms of focus area and the perspective considered (financial and non-financial). With the analysis, these models' applicability in today's business environment pinpointed the most usable models and their current shortcomings. Findings disclose current SCPEMs limitations and misalignments with the emerging disruptive technologies observed in today's supply chains. Given the findings, this study has highlighted the lack of overall supply chain performance evaluation and the failure to underline the underperforming decision criteria in the SC network. Therefore, to tackle these gaps, the authors have suggested visibility, leagility, collaboration, digitalization, sustainability, and integration as SCM characteristics to be considered in the future when developing a novel SCPEM. Finally, this study can be used as guidance for future studies.

1 Introduction

Due to the constantly increasing competition in global logistics and globalization, a new level of pressure is being applied to logistics service providers, originating from stakeholder groups, variations in customer demand patterns, and new legislation in sustainability-related requirements [1,2]. Given the recent developments in globalization, digitalization, and customers' knowledge base, supply chain management (SCM) has become an even more challenging task to excel in than it was just a few years ago [3,4]. Therefore, practitioners have been frantically seeking solutions to managerial issues and have been able to find them, at least in part, from the emergence of disruptive innovations such as digitalization and industry 4.0, which have significantly impacted current SC processes [5-7]. This challenge has led academics and practitioners to recognize the need for real-time level measuring, tracking, and optimization of supply chain performance to help firms cope with continuous pressures and achieve strategic goals while providing long-term value to ecosystems [8-10]. For companies, SC excellence is a key focus as it is their competitive advantage and business performance core element [11,12]. Correspondingly, performance measures, data, and metrics are required to reflect business objectives, assess current performance levels, and enhance the overall supply chain (SC) through efficiency and effectiveness, and more recently, sustainability [13]. Appropriate performance measures allow decision-makers to embrace a sustainable perspective and allocate firm resources toward the most efficient improvement activities [14]. On the other hand, inadequate key performance indicators fail to reflect an organization's crucial state [15,16]. Becoming a fundamental management tool, performance evaluation models are designed to assist SC managers in real-time measuring the impact of strategic, tactical, and operational decisions on the SC performance [9,17-19]. In addition, an effective SC performance evaluation model (SCPEM) requires suitable metrics adoption for SC process essence and enhancement point capturing needs [20,21].

There are several performance evaluation models, including Balanced Scorecard (BSC), Activity-based Costing, Economic Value Added (EVA), Supply Chain Operations Reference Model (SCOR), and Global Supply Chain Forum (GSCF). Each of these models could be used to evaluate SC performance depending on the organization's status and strategies [16,22]. Furthermore, the performance measurement outcomes reflect the effect of strategies and possible opportunities in SCM [23,24]. There are several purposes for developing performance evaluation models in SC, such as maximizing corporate performance, including profit and internal process effectiveness by cutting operating costs and increasing service quality, identifying customer needs fulfillment, having a comprehensive overview of business processes, ensuring and tracking progress, identifying bottlenecks waste, problems, and improvement opportunities, plus different SC new idea innovation and novel solution development requirements [7,11,25,26]. Accordingly, considering the overall SC is essential in developing a SCPEM.

Many literature reviews and papers on SC performance evaluation systems have been done in the last couple of decades. For example, Gunasekeran et al. [27] have provided an overview of different performance measures and metrics across SCs and have categorized them into strategic, tactical, and operational levels. Chan et al. [23] have classified performance measures into quantitative and qualitative criteria, and they have captured the key issues in SC. In other work, Akyuz and Erkan [28] have reviewed the papers in the field of SC, information technology, and performance measurement to establish a broad perspective covering different aspects, including people, technology, and processes. Subsequently, Hasan Balfaqih et al. [18] and Reddy et al. [10] have categorized the articles based on the approaches and techniques in the context of SC. To provide a clear definition of SCPMS, Maestrini et al. [17] and Guersola et al. [9] have conducted a systematic literature review in this field. They have, however, classified the literature by journal and discipline. Similarly, Elgazzar et al. [14] have conducted a literature review to provide a comprehensive overview of SCPMS development between 1995 and 2015. The authors have proposed a conceptual framework for the design and implementation of an SCPMS. More recently, Khan et al. [29] have reviewed the existing SCPMS in today's business environment. They have used a qualitative review methodology to determine whether existing SCPMSs are consistent with the current emerging supply chain performance management and measurement trends.

Although the issue of supply chain performance evaluation has been broadly debated in the literature during the last few decades, further research still needs to give more awareness to the functions and shortcomings of existing SCPEMs. Through a structured overview of the previous literature, SCPEMs are significant because they are the core managerial mechanisms for effective and efficient SCM. They are looked at as an appropriate way to improve SC governance by making it more timely, conscious, and more valuable decisions [30,31].

The proposed paper aims to conduct a literature survey to provide a comprehensive overview and better understand existing supply chain performance evaluation models (SCPEMs) applicability in today’s business environment, highlighting several SCPEMs drawbacks and suggesting new characteristics of the supply chain management to be considered in the performance measures. Moreover, this work is relevant to academics and practitioners in the area of supply chain management as it enriches the knowledge of current overall supply chain performance evaluation. The following research questions have been established for this study:

RQ1. What are the existing supply chain performance evaluation models (SCPEMs)?

RQ2. What are the SCPEMs' drawbacks and the gap between existing SCPEMs and the current trend of SCM?

Our contribution to SC performance literature is as follows:

1. Determine existing SCPEMs and their functions
2. Identify the knowledge gap in existing SCPEMs
3. Propose new SCM trends to consider when designing a SCPEM in the future.

The remainder of this paper is structured as follows. Section 2 goes into the methodology employed to carry out this study. Section 3 includes a literature review on existing SC performance evaluation models. This section seeks to provide a response to the first research question. The discussion and findings are presented in Section 4. This section responds to the second research question. Finally, the summarized conclusion is discussed in Section 5.

2 Research methodology

The scope of the paper is limited to existing supply chain performance evaluation models (SCPEMs) applicability, functions, and drawbacks. A structured literature survey has been undertaken using ISI Web of Knowledge and Scopus online databases to select the relevant articles to cover this scope. These two databases are the most extensive and widely used search tools in academia [9]. The search focused on studies that investigated SCPE systems, models, or frameworks between 2000 and 2021, as the majority of the research was done over this period. The search was restricted to peer-reviewed journal papers in English within the areas of industrial and manufacturing engineering, accounting, business management, and decision sciences. Supply chain performance, supply chain evaluation, supply chain performance evaluation, supply chain performance evaluation systems, supply chain performance measurement, performance measurement, and performance measurement systems were all utilized as keywords in the study. The selection was made based on the articles' titles, abstracts, and keywords.

From databases, a total of 281 articles (122 in Scopus and 159 in ISI Web of Knowledge) were identified. All abstracts were analyzed to exclude works not relevant to the research. By excluding duplicate papers, The final review resulted in a total of 70 articles for inclusion in the main analysis.

Figure 1 shows the literature search process, which is quite similar to the one conducted by Balfaqih et al. [18]. Other information, such as the distribution of articles regarding journals, is presented in Table 1.

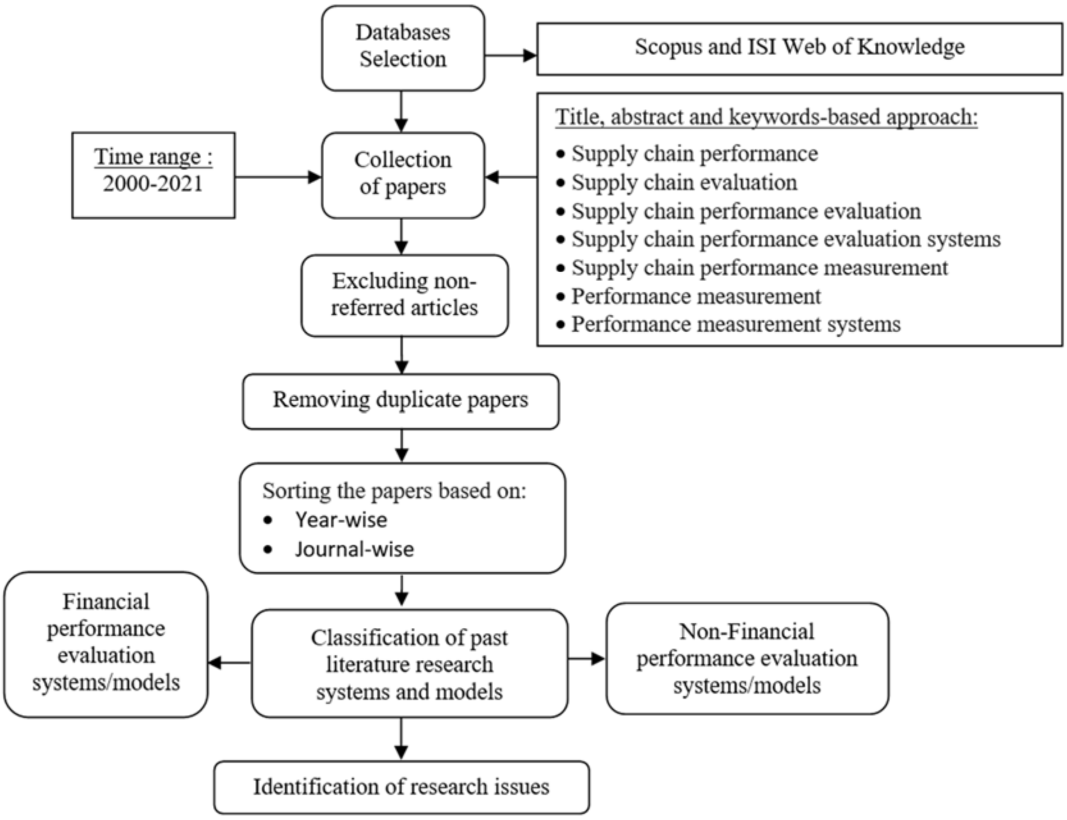

Figure 1 Research methodology

Table 1 Amount of publications per main journals

Academic Journal	Publications
International Journal of Production Economics	9
International Journal of Productivity and Performance Management	8
Production and planning control	7
Benchmarking	6
Journal of Cleaner Production	6
International Journal of Production Research	5
International Journal of Logistics Systems and Management	4
Computers and Industrial Engineering	4
Annals of Operations Research	4
Supply Chain Management: An International Journal	3
Sustainability	3
Computer in Industry	3
Uncertain Supply Chain Management	3
International Journal of Supply Chain Management	3
International Journal of Mechanical and Production Engineering Research and Development	1
International Journal of Industrial and Systems Engineering	1
Total	70

3 Literature review

In recent years, performance evaluation has become essential for any supply chain [32,33]. As global manufacturing has expanded, today's competition centers on supply chains rather than companies [33,34]. In other words, evaluating supply chain performance is critical to establishing and maintaining a competitive advantage in the marketplace [35,36]. According to Neely et al. [37], performance evaluation is a process, metric, or set of metrics aimed at quantifying activities' efficiency and efficacy. This shows how well-desired supply chain goals are achieved, including quality, time, cost, etc. [31,32]. Moreover, it helps decision-makers identify areas for improvement [35,38,40]. Additionally, a system for performance valuations can be defined as a system that merges information from multiple measures for efficiency and effectiveness qualification [23,37]. As it is clear, supply chain performance evaluation is essential for efficient SCM at both inter-organizational and cross-border processes [31]. Therefore, many researchers have tried to consider SCPEMs from different perspectives in the last couple of decades. Initially, works focused on developing an integrated framework, categorizing measures along with decision-making levels, and based on their nature (financial, non-financial) using Balanced Scorecard (BSC). Following that, attention has switched to other areas, most notably the identification of KPIs, adopting measures and metrics for SC resilience, green SC, and, more recently, considering digitalization aspects in SCP [18,39-42].

Based on the selected papers, this section has answered the first research question by presenting existing supply chain performance evaluation models.

3.1 Existing supply chain performance evaluation models

The significant amount of research and extensive published literature on SC performance emphasized the relevance of SCPEMs in the context of overall organizations' performance. Scholars and practitioners have discussed supply chain performance evaluation systems from several perspectives, including cost and non-cost perspectives, business process perspectives, strategic, tactical, and operational perspectives, and financial perspectives [28,43]. Executive management requires financial measures for management-level decisions, but bottom management needs operational standards for day-to-day operations [9,14]. This shows the importance of considering financial and operational measures to assess overall SC performance. Therefore, the authors have classified SCPEMs into two groups: financial and non-financial, and eleven sub-categories of non-financial categories, as shown in Table 2.

3.1.1 Financial Performance Evaluation Systems (FPES)

Although previous studies have widely considered supply chain performance evaluation [8,18,19,29], only a few research studies on supply chain financial performance evaluation have been undertaken [32,44]. Financial performance evaluation systems (FPES) have been defined as classical accounting methods for assessing SC performance. However, they have only focused on financial-based metrics and have been regarded as inadequate. They have failed to include vital strategic non-financial measures that affected its overall performance [29,32,43]. FPES are no longer useful for providing critical information to firms in today's dynamic market [44]. This is because the classical approach which emphasizes financial indicators lacks to adjust to competitive advancements and technology, resulting in internal financial data that is usually erroneous and misleading. Several papers have categorized FPES into various categories [29,43]. Nevertheless, the authors have considered ABC and EVA as the most well-known financial performance evaluation systems.

Table 2 Supply Chain Performance Evaluation models Classification

Financial Performance Evaluation Systems/Models	Activity-Based Costing (ABC)
	Economic Value Added (EVA)
Non-Financial Performance Evaluation Systems/Models	Supply Chain Operations Reference Model (SCOR)
	Supply Chain Balanced Scorecard (SCBSC)
	Global Supply Chain Forum (GSCF)
	Interface-Based Performance Evaluation system (IBPMS)
	Perspective-Based Performance Evaluation system (PBMS)
	Efficiency-Based Performance Evaluation System (EBPMS)
	Hierarchical-Based Performance Evaluation Systems (HBMS)
	Dimension-Based Performance Evaluation System (DBPMS)
	Process-Based Performance Evaluation System (PBPMS)
	Knowledge-Based Performance Evaluation system (KBPMS)
	Performance pyramid and prism-based model

3.1.1.1 Activity-Based Costing (ABC)

In an attempt to join operational performance and financial measures, Harvard Business School introduced Activity-based Costing in 1987. It constitutes estimating the resources regarding cost while the activities are being broken down into single tasks and cost drivers. The model is widely utilized for margin analysis and cost. ABC is implemented in five phases [45-47]: i) Identifying the firm's operations and various products to map processes. ii) Assignment of workloads and working hours to the various operations. iii) Development of a performance indicators system for assessing the output of cost-generating activities. iv) Identifying the number of resources utilized per product and, as a result, the related expenses. v)

Determining the product cost detailed by activity. The ABC method enables an accurate assessment of supply chain processes productivity and costs [29,45-47].

3.1.1.2 Economic Value Added (EVA)

The Economic Value Added approach was built by Stern in 1995 with the purpose of predicting the return on capital (ROC) of firms in terms of value-added and thus correcting the shortcoming in classical accounting methods, which focus solely on short-term financial outcomes that are unable to provide long-term value-added to companies and their shareholders [48,49]. This approach was founded on the principle that when a firm earns more than its cost of capital, the shareholder value increases. EVA seeks to measure an organization's value, focusing on operating profits over capital employed (through debt and equity). Therefore, it is beneficial in determining long-term shareholder value and high-level executive contributions [29,48,49].

3.1.2 Non-Financial Performance Evaluation Systems (NFPES)

The non-financial performance measures have been introduced to provide extra information which the conventional approach could not offer [9,14]. Although financial indicators are the most used in top-level management where strategic decisions are made, they are not relevant in daily operations because they are only available after SC operations have been completed. This shows the importance of non-financial measures in organizational performance since they assist low-level management with day-to-day operations. Non-financial SCPEMs have been developed so far upon reviewing the literature in the field of SCPM [8,18,22,29,43,50,51]. The authors have classified NFPES into eleven sub-categories.

Following is the description of NFPMS:

3.1.2.1 Supply Chain Operations Reference Model (SCOR Model)

The SC Council formed the first version of the SCOR model in 1996. This model was developed to describe the management process related to all phases involved in meeting customer demand. Therefore, it allows companies to boost both the efficiency and effectiveness of their SC [9,18,22,52,53]. The SCOR model has two dimensions: SCOR processes (plan, source, make, deliver, return, and enable) and performance criteria (reliability, responsiveness, agility, cost, asset management efficiency). Thus, it is arranged in a 5x6 matrix [54]. The SCOR model has been regarded as a supply chain assessment framework, as it defines and categorizes the processes that construct the chain, allocates metrics to such processes, and reviews similar benchmarks [18,28,53,55]. The latest version of the SCOR model (SCOR 12.0) was released by ASCM in 2017 and is currently used in many manufacturing industries [53,54,56]. Nowadays, there are over 250 SCOR metrics in the framework drawn from board members' experience and contributions [54,56].

3.1.2.2 Balanced Scorecard Model (BSC Model)

The BSC model has been recognized as a leading tool to evaluate long-term corporate performance from multi perspectives, including financial perspective, internal business process, learning and growth perspective, and customer perspective [15,36,57]. The BSC concept was coined by Kaplan and Norton in 1992 to better reflect the real performance of the company and select and combine performance metrics from a balanced view. The BSC model includes traditional financial measures reflecting past performance and operational (non-financial) representing future performance drivers. It also helps decision-makers rapidly improve their activities and operations and aims to enhance internal and external corporate functions [15,18,36,51]. Metrics within the BSC perspectives are chosen based on the firm's strategic objectives. As a result, decision-makers can convert strategies into a set of metrics that can be used to track a strategy's overall effect on the business [15,36,57].

3.1.2.3 Global Supply Chain Forum (GSCF)

The GSCF framework was established by Ohio State University in 1994. The primary purpose was to describe the standards of supply chain processes at different decision-making levels [22,58,59]. This model has focused on the SC network structure, SCM components, and SCM processes. The Global Supply Chain Forum has identified eight key processes that construct the core of SCM, namely, customer service management, customer relationship management, demand management, managing manufacturing flows, order fulfillment, product development and marketing, supplier relationship management, and returns management [22,58,59].

3.1.2.4 Interface-Based Performance Evaluation System (IBPMS)

IBMS was introduced by Ohio State University in 2001. In this framework, the performance of each phase is related to the SC network [29,43,50]. It aimed to keep track of how customer relationship management (CRM) and supplier relationship management (SRM) systems interacted at each stage of the supply chain [29]. The IBMS framework aimed to develop supply chain metrics that translate performance into shareholder value to maximize shareholders' value for the overall SC along with each company [29,43].

3.1.2.5 Perspective-Based Performance Evaluation System (PBPMS)

PBPMS was conceptualized by Otto and Kotzab (2003) as an inter-functional measurement system [60]. It looks at SC all potential perspectives and provide measures and metrics to assess each perspective. They have defined perspective as a unique vision of what SCM is about

[18,29,60]. These perspectives are system dynamics, logistics, operations research/IT, marketing, organization, and strategy. However, some of the proposed metrics are not used in business practice. Furthermore, a trade-off between one perspective measure and another perspective measure may exist. Previous studies have classified it into two sub-categories, the BSC and SCOR models [18,29,61].

3.1.2.6 Efficiency-Based Performance Evaluation System (EBPMS)

EBPMS are systems that quantify SCP in terms of efficiency [29,43]. Several approaches and frameworks have been developed in this context (Negi et al. [11], Sharma and Bhagwa [62], Rodríguez et al. [61], Izadikhah et al. [63], and Hahn et al. [64]). These systems are able to measure and evaluate the various units' SC efficiency linked to each other but not beside the target value or benchmarking [29]. Most of these approaches are based on data envelopment analysis (DEA), measuring internal SCP related to efficiency [29,63].

3.1.2.7 Hierarchical-Based Performance Evaluation System (HBPMS)

In 2004, HBPMS was developed by Gunasekaran et al. [31]. It has been used in three aspects: metrics, criteria, and processes. Metrics have been categorized at strategic, tactical, and operational levels, which mirror the relevant amount of management authority, control, and influence for the performance [30,33,65]. These metrics have also been divided into financial and non-financial [18,29,43]. The purpose of the model was to make fast and fitting decisions. Generally, This model links the performance measures with firms' objectives [30,43,66]. Many hierarchical frameworks have been developed. For example, Bhagwat and Sharma [62] have classified the metrics related to the three hierarchical levels. Moreover, they focus on metrics in the global competitive environment so that managers can make suitable decisions. Luthra et al. [66] have suggested an integrated framework to select and assess sustainable suppliers using AHP (Analytical Hierarchy Process). In other work, Venkatesh et al. [67] have developed a framework based on fuzzy AHP-TOPSIS (Technique for Order Performance by Similarity to Ideal Solution) to solve partner selection problems.

3.1.2.8 Dimension-Based Performance Evaluation System (DBPMS)

DBPMS concept is founded on the principle that any SCP can be evaluated in terms of dimensions [29,50]. Beamon has identified three criteria to assess SCP, namely, flexibility, resources, and output [29,43,68]. These measures are needed in SCPE. In other words, supply chain performance evaluation systems must take these measures into account as they are key success factors for the overall supply chain performance [14,29,69]. Examples of resource performance measures include manufacturing cost, inventory cost, and return on investment (ROI). Output measures comprise total sales, fill rate, and on-time deliveries, whereas flexibility parameters measure in terms of volume changes and new product introduction. Otherwise, various works have suggested other dimensions to evaluate SCP. For example, Ferreira and Silva [70] have integrated sustainability metrics In SCPMS. Similarly, Kafa et al. [13] have suggested green supply chain performance measurement metrics. More recently, Neri et al. [71] have proposed a set of metrics based on BSC dimensions and TBL (Triple Bottom Line) criteria (Social and Environmental). Their framework addressed different decision-making levels. In another work, Zekhnini et al. [72] have suggested a model for supply chain performance based on metrics related to digitalization and sustainability. Rasool et al. [73] have addressed the digital supply chain, suggesting metrics based on BSC dimensions.

3.1.2.9 Process-Based Performance Evaluation System (PBPMS)

SCM refers to processes and activities integration from supplier to end customer. Due to this fact, it is vital to understand key SC processes and activities to develop an efficient performance measurement and evaluation system [14,18,74,75]. Many researchers have used PBPMS to evaluate SCP. For example, Lin and Li [76] and Charkha and Jaju [77] have used six-sigma metrics to assess the overall supply chain performance. In another paper, Chan and Qi [75] have studied the feasibility of SCPMS based on process-based metrics. They have considered five processes (supplying, inbound logistics, core manufacturing, outbound logistics, and marketing and sales). Gunasekaran et al. [31] have considered four supply chain processes (plan, source, make, and deliver) in their framework using a process-based approach. Persson and Olhager [78] have defined the SC as a set of processes to evaluate SC entities. Their case study was conducted in the mobile communication industry. Lima-Junior and Carpinetti [79] have used SCOR metrics to predict supply chain performance. Their framework is based on Artificial neural networks (ANN) as they allow a suitable adaptation to the dynamic environment by employing historical performance data. Ikatrinasari et al. [53] have conducted a framework based on SCOR metrics to improve supply chain performance. Their research has focused on printing services companies. Hence, they have recommended four performance criteria to consider; namely, Reliability metric: Perfect Order Fulfillment (POF), Responsiveness metric: Order Fulfillment Cycle Time (OFCT), cost metric: Cost of Goods Sold (COGS), and assets metric: Cash to Cash Cycle Time (CTCCT).

3.1.2.10 Knowledge-Based Performance Evaluation System (KBPMS)

Recently, knowledge has become one of the key factors in providing competitive advantage and continued development and success for supply chain partners [35,38].

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Every decision is vital for SC performance and impacts directly and indirectly on overall supply chain performance. Therefore, the knowledge of decision-makers is needed in assessing supply chain performance [29]. KBPMS have been developed due to digitalization and Industry 4.0 requirements and have been considered smart SCPMS [29,35]. Previous works have focused on using knowledge to evaluate overall supply chain performance. For example, Khan et al. [35] did produce a knowledge-based system (KBS), which gave them the possibility to establish the relationship between short-term and long timeframe based decisions and the decision criteria performance of related supply chain, as well as incorporate knowledge between SC partners for accurate overall supply chain performance evaluation. They have used fuzzy AHP to implement their framework. In another work, Khurshid Khan and Wibisono [80] have considered five SCP perspectives: a business perspective, customer perspective, manufacturing competitive priorities perspective, internal process perspective and resource, and method availability perspective using KBPMS based on AHP. As a result, their model has looked suitable to assist decision-makers using PMS and offers relevant and thorough prioritized outcomes for actions and improvement.

3.1.2.11 Performance pyramid and prism-based model

As a top-down approach, the performance pyramid integrates corporate strategy with its operations by converting upper objectives (based on consumer priorities) and underside metrics. [22,29,81]. However, this model fails to provide an instrument to identify key performance indicators [29,81].

The performance prism is a framework for five performance measures evaluation (stakeholder satisfaction, strategies, processes, capabilities, and stakeholder contributions). The performance prism provides a far more full view of various stakeholders (e.g., investors, consumers, workers, regulators, and suppliers) than other frameworks. However, although the performance prism extends further than classical performance evaluation, it provides little about how the performance measures will be achieved [29,81].

4 Result and discussion

Based on the found and mapped foregoing body of knowledge in academics, it is argued that numerous models and frameworks for monitoring and analyzing supply chain performance have been established. Both qualitative and quantitative metrics of financial and non-financial nature have been included in performance evaluation models across the supply chain. However, due to the competitive environment and the emergence of disruptive technologies such as digitalization and industry 4.0, and new legislation in sustainability-related requirements, the reviewed existing models and frameworks of SCP evaluation still face utilization drawbacks and practical applicability limitations. Below, Table 3 highlights several limitations of existing models and frameworks of SCP evaluation and their focus area.

Table 3 SC performance evaluation systems/models: focus area and limitations

SCPEM	Sub-categories	Focus area	Limitations	Reference
Financial Performance Evaluation Systems/Models	Activity-Based Costing (ABC)	Cost and margin analysis	- Focusing solely on financial measures and metrics. - Time-consuming and costly to sustain. - Difficult to implement in small companies.	[29,45,46,82]
	Economic Value Added (EVA)	Financial indicator: Return on capital	- Focusing solely on financial measures and metrics. - Inadequacy of EVA for small companies and certain industries such as the technology sector. - difficult to determine the exact cost of equity.	[29,43,48]
Non-Financial Performance Evaluation Systems/Models	Supply Chain Operations Reference Model (SCOR Model)	Address, improve and communicate SCM decisions among SC partners	- Heavy focus on flows of information without including all related SC activities. - The lack of a learning technique allows quantification of cause-effect relationships among metrics in a specific application environment. - Overall performance evaluation is rather complex. - Not flexible if there is a change in the assessment. - Corporate sustainability issues are not included within the scope of SCOR. - There are over 250 SCOR metrics, so selecting and monitoring all these metrics is time-consuming. - It does not take into account the global perspectives on market uncertainty.	[18,22,43,52,53, 55,79]
	Balanced Scorecard Model (BSC Model)	Evaluate long-term corporate performance from multi perspectives, including financial	- It cannot evaluate the overall performance and highlight the under-performed KPI criteria. - Lack of coordination along with the SC network. - The relationship between short-term and long-term decisions and SC performance measures (short-term	[15,36,43,51,57, 61,83]

		perspective, internal business process, learning and growth perspective, and customer perspective.	and long-term) for accurate overall SC performance evaluation is lacking. - BSC is designed as a control tool rather than an improvement tool that emphasizes guidance at the strategic level rather than the functional or operational level. - It does not enable quick decision-making, highlights under-performed criteria, and fails to assess overall SC performance. - It doesn't cover sustainability and digitalization perspectives.	
	Global Supply Chain Forum (GSCF)	Describe supply chain process standards at different decision levels.	- How the processes are carried out and handled is unclear. - It does not cover all SC functions. - It does not consider financial flow. - External benchmarking is missing. - It does not include sustainability issues and quality impacts.	[22,58,59]
	Interface-Based Performance Evaluation System (IBPMS)	Linked performance of each SC network member.	- Requiring complete transparency and information openness in all stages can be a challenge to implement.	[29,43,50]
	Perspective-Based Performance Evaluation System (PBMS)	Evaluate SC performance in terms of six main perspectives: system dynamics, operations research, logistics, marketing, organization, and strategy.	- A trade-off between one perspective measure and another perspective measure is possible.	[18,29,43]
	Efficiency-Based Performance Evaluation System (EBPMS)	Evaluate SC performance in terms of efficiency.	- It does not provide any link between supply chain functions. - Requirement of accurate measurement for both the inputs and outputs. - Most EBPMS are solely based on the DEA technique and ignore the other MCDM tools. - Uncertainty is produced in the decision-making process.	[9,35,43,64]
	Hierarchical-Based Performance Evaluation System (HBPMS)	Assess SC performance at various stages of decision-making (strategic, tactical, and operational).	- There are no specific guidelines for reducing different levels of conflict throughout the whole SC network.	[18,29,43,62]
	Dimension-Based Performance Evaluation System (DBPMS)	Assess SC performance with regards to dimensions.	- It is not considered physical flow. - It only focused on strategic measures. - It cannot highlight the under-performed KPI criteria at any decision-making level in the whole SC network.	[22,35,43,51]
	Process-Based Performance Evaluation System (PBPMS)	Evaluate SCP considering the key operational process of SC.	- Time-consuming when integrating all processes and activities within the PMS. - It is difficult to decide which process should be improved to achieve a specific performance goal. - Not flexible if there is a change in the assessment.	[14,18,75]

	Knowledge-Based Performance Evaluation System (KBPMS)	Evaluate SCP based on the decision-makers' knowledge.	- A survey of various firms should be conducted to verify the required short-term and long-term criteria to be included in the KBS. - A KBPMS conducted by Khan et al. is only implemented in the automotive sector and should be carried out in other sectors. -The suggested KBPMS by Khan et al. is not executed by establishing links between distinct SC functions.	[29,35,38]

Subsequently, the authors have discussed the current trends in monitoring and managing SC and highlighted the impact of technological advancements in business performance. Based on the literature analysis, it is argued that traditional SCPEMs fail to deal with the complexity of SC. Therefore, the authors have identified some gaps in existing supply chain performance evaluation models, which are as follows:

- Existing SC performance evaluation systems have a poor financial and non-financial measurement balance.
- Previous SCPE frameworks have not captured both the digitalization and sustainability aspects.
- Lacking in assessing overall supply chain performance.
- Fuzzy information and data are used in assessing overall supply chain performance.
- Existing SCPEMs are unable to integrate short-term and long-term decisions and decision criteria.
- Lack of underlining of underperforming decision criteria in the SC network.

Based on the gaps mentioned above in current SCPEMs, it is stated that to make fast decisions for monitoring SCP effectively and efficiently and achieve a high degree of satisfaction for decision-makers, SCPEMs must keep up with new trends in SCM.

Below, the authors have summarized the anticipated trends in need of efficient supply chain performance evaluation:

- **Visibility**

Supply chain visibility helps to improve inventory levels, decrease uncertainty, risk, and bottlenecks, and optimize SC operations. Meanwhile, the visibility aspect is a major challenge in traditional SC operations because when problems occur in SC functions, they can worsen and further propagate down the chain. Therefore, it is challenging to manage and track these issues due to the complexity of the supply chain. This shows the importance of visibility in SC, and companies must be transparent in their order processing and provide ongoing feedback and order status to their consumers. Correspondingly, the emergence of disruptive technologies has increased the transparency of the overall value creation process [5]. This leads the decision-making process more collaborative and efficient. To cope with this trend, it is required to implement a SCPEM that will deal with the following challenging trends in SCM.

- **Leagility**

Supply chain leagility is a blend of agility (fast reaction and service) and leanness (total cost optimization) within the whole SC strategy [7]. Previously, lean and agile were thought to be two distinct types of supply chain operations [84]. These two terms have a high impact on efficiency, cost, service, and speed. Generally, leagility is more suitable in supply chains where end-customer demand is volatile and unexpected, but ultimate customers are also price-sensitive. Despite the importance of this trend in SCM, it is revealed that supply chain performance evaluation models also need to use the Internet, IoT, and cloud computing to timely identify, monitor, track, and analyze the changes in all supply chain links [7]. By implementing leagility in the whole SC network, the service quality will be assured, as well as low inventory cost downstream, the stability and efficiency of upstream manufacturing and operations [7].

- **Collaboration**

Collaboration and proper trust between various SC functions are needed to improve supply chain performance [85]. Therefore, decision-makers need to collaborate to understand their needs, expectations, and each other's responsibilities. This will help eliminate repetitive tasks and improve each function's performance and the quality and efficiency of customer deliveries [29,38]. The reviewed existing supply chain performance evaluation models lack strong collaboration among SC functions and lack suitable methods to improve overall supply chain performance. As a result, SCPEMs need to collaborate with different SC functions and boost overall SC performance.

- **Digitalization**

Digitalization helps companies create transparency, improve the quality and efficiency of supply chain processes, modernize business models as well as track and monitor all activities, assets, and operations electronically [86]. This will provide decision-makers with a holistic view of the whole supply chain and help them make fast decisions related to SC functions [5,42]. Unfortunately, the reviewed SCPEMs are not suitable for capitalizing on the benefits of digitalization measures and improving overall supply chain performance. To cope with this trend, it is required to design supply chain performance evaluation systems that include digitalization measures and enhance overall SC performance.

- **Sustainability**

Unlike classical SCM, sustainable SCM helps companies increase profitability and, at the same time, it helps to minimize negative environmental effects and increase social welfare [87]. On the other hand, sustainable SCM requires companies to take financial feasibility into account when considering the sustainable part of their SCs [88]. This highlights the importance of changing the focus of supply chain performance management from operational excellence to social and environmental responsibility [9,69]. Therefore, integrating the issue of sustainability into supply chains will improve the environmental, social, and financial performance of supply chains [71]. Meanwhile, this will give decision-makers a comprehensive view of the overall supply chain based on triple bottom line factors (environmental, social, and economic) and help them make accurate and rapid decisions related to SC functions. The reviewed SCPEMs lack the introduction of measures and metrics to evaluate the sustainability performance of supply chains, given the complexity of the decision-making processes. To deal with the sustainability trend, it is required to design supply chain performance evaluation models that consider the sustainability performance and track the indicators that support decision-making and improve the whole SC performance.

- **Integrated SC**

An integrated supply chain is an association of customers and suppliers that collaborate to improve their collective performance in creating, distributing, and supporting a final product utilizing management approaches. Integration among SC functions has become vital for efficient SC [29,89]. Therefore, it reduces bullwhip effects and enhances overall SC performance. Each SC process and its related measuring criteria impact the whole SC performance. Integration within SC is also important to provide relationships between long-term (strategic and tactical) and short-time (operational) decisions and decision measures [29,38]. This will help decision-makers make suitable decisions and understand their impact on overall supply chain performance. To align existing SCPEMs with this trend, an integrated supply chain performance evaluation system that encompasses all SC activities, provides relationships between decisions and decision measures, and assesses overall SC performance is required.

5 Conclusion

The value of the study is connected to the comprehensive review of existing supply chain performance evaluation models over a time span of 21 years (2000-2021) by reviewing academic research published in relevant peer-reviewed journals using ISI and SCOPUS databases. This study was focused on answering two set research questions:

RQ1. What are the existing supply chain performance evaluation models (SCPEMs)?

Before answering the RQ1, the authors have provided background knowledge on previous works and studies related to supply chain performance evaluation. Therefore, they have emphasized the development of this field over the past two decades. The review indicates that a substantial number of papers have been contributed to the field of supply chain performance.

In response to RQ1, the authors have conducted a literature survey based on 70 selected articles. They have classified SCPEMs in terms of focus area and the perspective considered (financial and non-financial) and found out their applicability in today’s business environment. The review revealed that the SCOR model and BSC are the most widely applied supply chain performance evaluation frameworks. Meanwhile, they have several limitations, as mentioned in table 4.

RQ2.What are the SCPEMs' drawbacks and the gap between existing SCPEMs and the current trend of SCM?

To answer the RQ2, the proposed work discusses various limitations and drawbacks of each SCPEM in Section 4. This leads to identifying the knowledge gap in existing SCPEMs, as indicated in Section 4. Findings reveal that existing supply chain performance evaluation models are not aligned with the emergence of disruptive technologies observed in SCM. Therefore, the authors have recommended some SCM trends to be considered in the future when designing a SCPEM. For example, integration between each SC function will help improve productivity, quality, and customer satisfaction effectively and efficiently because disruptive technologies have made SCM complicated nowadays. This shows the importance of designing an integrated model that enables the traceability and transparency of all supply chain activities, incorporates all SC functions, and provides relationships between long-term (strategic and tactical) and short-time (operational) decisions and decision measures and evaluates overall SC performance. Moreover, given the competitive environment and the emergence of disruptive technologies such as digitalization and industry 4.0, and the importance of environmental and social criteria as key elements for business success, developing supply chain performance evaluation systems that include digitalization, sustainability measures and sustainability reporting capabilities [90] to improve overall SC performance are recommended as future research. This work illustrates the main characteristics that should be considered when designing and developing a SCPEM in a new business environment. Therefore, the suggested study is a solid basis for both academics and decision-makers in the field of supply chain management.

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CAUSES AND EFFECTS OF SUPPLY CHAIN NERVOUSNESS: MENA CASE STUDY

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Abstract: As part of the global supply chain (SC), Middle East and North Africa (MENA) SC is subject to many disruptions and instability resulting in an unpredicted interference among decisions causing SC nervousness (SCN). Nervousness reduces the efficiency and negatively impact the overall SC performance. Nervousness greatly effect supply chain stability and resilience leading to an increase in costs and fluctuation of the relationships with suppliers as well as customers. This research explores the supply chain nervousness (SCN) in MENA region. An investigation of the existing literature and interviews with the experts used to identify factors related to nervousness in the SC. This study was prompted by a lack of research depth to identify and investigate the main causes, effects, and measures, of SCN. A survey is used to analyze and asses the SCN in the region. A comprehensive framework of SCN in MENA region is presented and analyzed. The results identify the major sources, causes, and impact of SCN, and then arrange causes based on their impact. Also, the relative criticality of nervousness factors was assessed using the Delphi based analytical hierarchy process (AHP). Furthermore it investigated the factors and response strategies to mitigate the nervousness sources. Finally, a list of measures is proposed to reduce the SCN and improve competitiveness, effectiveness, and responsiveness. Identification and assessment of nervousness factors enables professionals to take appropriate mitigation strategies, help companies decide plans to reduce nervousness in their SCs, and lead to better decisions on future resilient supply chains.

1 Introduction

The MENA region suffers from special conditions and exceptional circumstances, which have had a great impact on the supply chain and its performance, particularly, in light of the fact that the region is the center of attention by most countries of the world as consumers of their goods and products. There are several factors that affect the supply chain in the region, including political, social, economic conditions, and wars that almost never end in the region. As well as the supply chain of defense equipment, which is almost endless, and the region is one of the largest consumers of weapons and defense equipment as a result of the circumstances and surrounding crises. These conditions, in addition to the large number of partners, intense competition, sudden change in demand, lack of environment concerns, delay in response or delay in financial transactions, and the lack of interest of logistic companies in the region in exchanging information with their partners in the chain led to instability and SCN, which had negative repercussions on prices, times, and the level of services between consumers and suppliers. In general, MENA-SC is greatly affected by the SC nervousness.

Nervousness leads to a number of problems, including an increase in inventory, delays, costs, and the occurrence of mistrust between organizations and their suppliers on the one hand, and with customers on the other hand. It causes ineffectiveness of the supply chain in general, especially since most of the instability in this supply chain is caused by external events outside the company control. To the best of our knowledge, there is no previous study or research that considers nervousness in the MENA supply chain and analyzes it in terms of causes and their effect. Especially with the disruptions caused by Pandemics like COVID19 , which has special and exceptional impact that have led to a lot of instability in the supply chain and an increase in the costs of sustaining the supply chain and relationships with suppliers and customers. In this paper, an analytical study is presented showing the sources, causes of SC nervousness and their impact. Factors responsible for SCN are examined and prioritize using Delphi-AHP technique. Furthermore, response strategies to mitigate the nervousness sources are investigated. Because of the scarcity of research that deals with SCN, especially in MENA region, this study is unique and unprecedented in terms of analyzing the SCN in the region's supply chains. This research will help practitioners, executives, and managers understand and explore their SCN.

As shown in Figure 1, the methodology of this research includes a review of previous studies, data collection using a survey to identify the main reasons of nervousness and its impact on decision-making process, arranging the sources of SCN based on the expertise opinion, and identifying the characteristics and components including the main sources, causes that may lead to SCN and their expected impact. After that, a framework will be presented to describe the nervousness of the supply chain in the region and analyze its impact on the effectiveness and efficiency of the supply chain. This is followed by the proposed list of measures to reduce the SCN and improve future efficiency and resilience. Furthermore, the criticality of nervousness factors is assessed using the Delphi based AHP method. Finally, an approach for dealing with nervousness and the findings and recommendations for future research is presented.

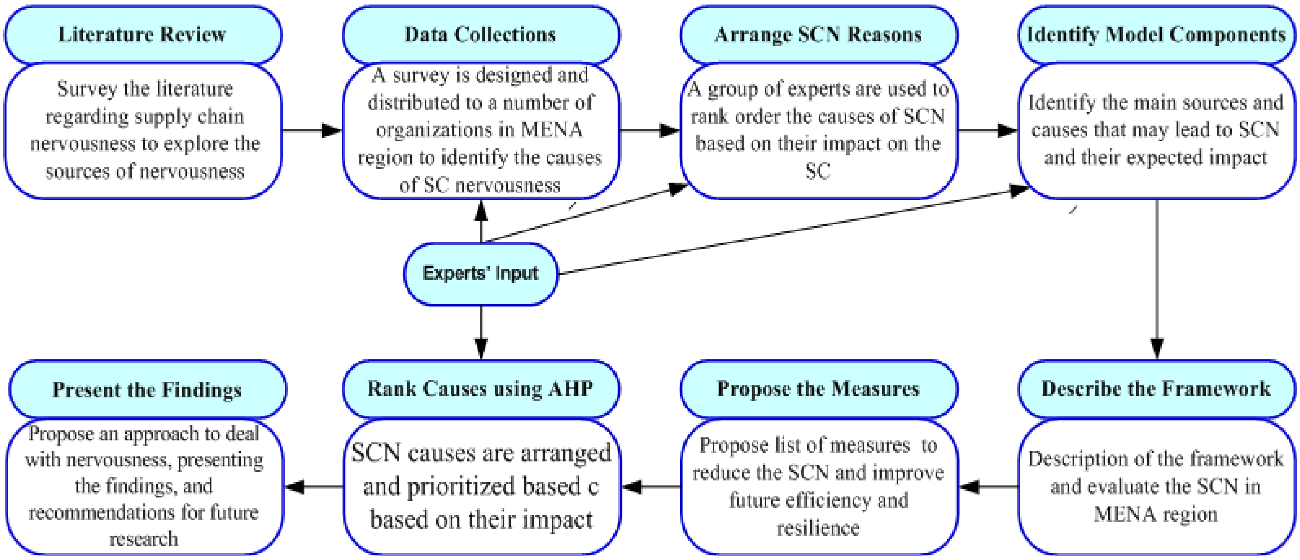

Figure 1 Research methodology

2 Literature review

Disruption in the supply chain cause post instability as a result of order delay and inventory accumulation. Shift of the residuals into post disruption cause a further delay and instability in the normal operations. To mitigate the instability effect there should be coordinated contingency procedure to prevent disruption [1]. Due to supply disruptions, demand instability, and government initiatives to combat the problem, the COVID19 pandemic had an impact on SC activities, operations, procedures, and management. The stress and panic caused by nervous decisions has an impact on SC operations and performance [2]. Political issue greatly effect supply chain management and it is implementation [3]. The change at one end of the supply chain greatly increases the shift from the steady state at the other end [4]. International crises taking into consideration financial instability effect the reaction of SC [5].

Nervousness results from time to time variability of orders given to the suppliers and resulted in a forecast error. Normal and proportional policy will reduce the bullwhip influence, SC inventory cost, and instability [5]. Systems nervousness results from the frequent review of the replenishment decisions because of the stochastic demand when coordinating the SC inventories [6]. Demand and supply are greatly affected by the rapid change in the market and the product variation. Demand planning accuracy vary among the SC partners and planning nervousness cause the bullwhip effect as the variation in demand amplified when sharing the information with the SC parties [7].

Globalization of the SC supporting the agglomeration and spreading and become healthier due efficient use of developing countries low cost labor but became less stable [8]. Currently with the growing of virtual SCs, companies not any more compete but the supply chains and the vertical integration is outdated. There is a need to visible the whole supply chain effectively to compete with others in the SC [9].

The integration of the dynamic SC functions can respond quickly and effectively to SC interruptions and changes and provides unique ability to current SC decision support systems [10]. The dynamic replenishment system can react successfully and efficiently to normal and disruptive supply chain operations [11]. Integration of supply chain segments with dynamic replenishments can improve partnerships, cost reduction and SCM efficiency [12,13].

SC nervousness associated with instability such as changes in task, source and SC uncertainties. These Uncertainties can be transformed into information processing which should be at the SC level. Sustainable SCM needs to turn into an organization’s daily business to shape the SC of the future [14]. Supplier innovativeness and information sharing expedite collaborations in the global SC [15]. Sustainable SCM can improve economic, social, environment in global supply chains [16].

Performance of today SC relies on the accuracy, quality, and timing of the shared data between partners. Many companies used electronic data gathering systems, cloud computing based SC, and software applications to support collaboration among all SC segments to develop new innovative products [17]. Suppliers' innovation is necessary for the process of development of new products and there is clear relationship between supplier integration and performance [18].

Nervousness can be understood of as "*a source of confusion or instability in the SC system caused by unexpected interference between decisions*" [19]. There is a connection between SC nervousness and demand planning and the bullwhip effect leading to a tangible difference in planning accuracy among SC partners [20]. The joint consideration of MRP nervousness and bullwhip effect in multi echelon SC reveals the system nervousness at various stages of SCs [21]. Planning nervousness should consider the relevant attributes of SC performance as there is a strong relationship between SCN planning and other SC segmentations [22].

While (23) discuss nervousness in the environment of current MRP strategy revisions, published research on nervousness in either modern GSC system or their impact framework are rarely exists. Nervousness is considered a major source of instability in the current and future SC resulting from unexpected interventions among decisions. Furthermore, there is no previous research investigates the supply chain nervousness in terms of causes and rank the SC nervousness sources based on their impact. This study was prompted by a lack of research depth to identify and investigate the main causes, effects, and measures, of supply chain nervousness. This research proposes an analytical framework for investigating nervous supply chains in MENA region, rank the causes using AHP method based on their criticality, and suggests a set of measures to mitigate SCN.

3 Causes of SCN

To identify the sources of SCN, a survey was developed and distributed to thirty leading organizations in MENA region. The survey consists of three major sections where each section aims to explore a side of the SCN causes: the first part ask about the SCN sources and causes and asked the respondent to rank order SCN causes based on their impact on their SCs, the second section concern about the impacts and effects of SCN sources and the sequences of the specified cause, the third part require the respondents to suggest measures to reduce the SCN. The survey consist of several questions including: the main sources of supply nervousness, causes of each type of source of nervousness, noise factors that are uncontrollable by SCs and contribute to the increase of the impact of nervousness, the risks associated with each cause of nervousness, the expected impact of nervousness on the supply chain operations and process, and the measures and metrics taken to reduce nervousness. Twenty four respondents answer the survey questions.

The literature review is utilized to list the available sources, causes, factors, and the impact of nervousness, as well as the measures mentioned in the reviewed articles. The data driven from the literature review, which represent the current nervousness factors worldwide, were made available to the experts to consider them in their decisions. A group of experts are used to identify the major sources and causes of SCN, study their impact, and cluster the causes in main and sub groups. It was also the role of the experts to rewrite and shorten the causes and effects, as they were given in different wordings and phrasing by the responses to the questionnaire.

Based on the literature, survey results, and the experts' opinion, Table 1 shows the main causes of SCN. The first column shows the sources of supply chain nervousness. The second column shows the causes of each source on the supply chain performance and operations. While the third/ frequency column indicates the number of respondents who included the reason specified in the cause column. For example, the first block in the frequency column specify that 23 respondent consider the "change in customers' need" as a source of SCN. The source reasons are arranged in descending order according to the number of times mentioned in the responses. Similarly, the causes for each source were arranged in descending order depending on the results of the questionnaire analysis.

All responses are summarized in ten main sources and their related causes. The largest number is for the variations in customer needs flowed by the crisis and disasters, while the smallest number is for the lack of integrations.

Based on the respondent answers to the third part of the questionnaire, the rank order of SCN sources based on their impact on their SCs are shown in Figure 2. The values were calculated using the following equation (1):

$$R_i = \frac{\sum_{j=1}^{n} r_{ij}}{n} \quad (1)$$

Table 1 Causes of SCN

No.	Source	Cause	Frequency
1	Changes in customers' needs	Fluctuation in demand, change in production plan, change in inventory and stock policy, error in demand forecast, change in market place, change in products, competitor's advantages, and prices change	23
2	Disasters and crisis	Natural disasters such as earthquakes, dust storms, volcanos, storms, heat wave, diseases and its effect. Manmade disasters like ethnic and religious violence, Terror attacks, income equality, industrial accidents, refugees, migrations. Technological disasters like nuclear radiation, chemical accidents, biological propagation, power outages, climate change, natural gas explosions, and unplanned urbanizations.	20
3	Risk of supply continuity	Sporadic supply of raw material, unavailability of supply, instability in prices, shortage of resources, delivery conditions, political instability, fluctuation of quality and quantity, geographical instability, climate deviations, water shortages, and store nationalism	19
4	Safety and Security concerns	Security of the SC activities like transportation, shipping and handling, and all logistics practices, cyber security, risks, safety issues, the challenges of e-commerce, smuggling, piracy, cloud risk, devices interferences, poor quality hardware, local security on the facility itself, physical security to transportation for example, fraud, cargo theft, and virtual security.	18
5	Geopolitical instability	Change in state policies, regional conflicts, rapid changes of allies, crisis or wars, terrorism, UN resolutions, economic sanctions, and governmental lockdown.	17
6	Social unrest	Unemployment, inequality, financial crises, government failures, marginalized, disease epidemics, the anarchy of the sects, political instability, energy, food, discrimination, strikes, demonstration, objections to some products, high prices , and change in purchasing behavior and power.	17
7	Keeping pace with developments	Emerging trends, new technology, new product design, increased demand for quick responsiveness, low price, adopt new systems, new business trends, shorter products life cycle, and shorter product development cycle.	15
8	Environment concerns	Heat waves, flood, wildfire, and global warming, air pollution, toxics emissions, temperature changes, the seasons shifting, water shortage, oppressive land use, water pollution, energy usage, and contaminated waste, oil and chemical pills, and remediation and land reclamations.	11
9	Economic context	Risk of government decisions, tariffs, administrative and operations weaknesses, natural disasters, Bankruptcy, currency fluctuation, adequacy in SC infrastructure, outsourcing, redundancy systems, investment in wrong business, conflict of interests, global growth, international monetary system, shipping routes, sanctions, volatility in the international oil market, populism by country leader, trade competition between countries, political influences, socioeconomic causes, inflation, tariffs on trade, global financial system, and environmental considerations	9
10	Lack of integration	Objectives mismatch, difference in planning accuracy between partners, variance in decision-making process, overlapping interests, and lack of trust, commitment, transparency, IP protection, collaboration, partnerships, alliances, of information sharing, planning coordination, and operation flexibility.	7

Where r_{ij}: rank of source *i* by respondent *j*, *n* represent the total number of respondent and R_i represent the rank of nervousness source *i*.

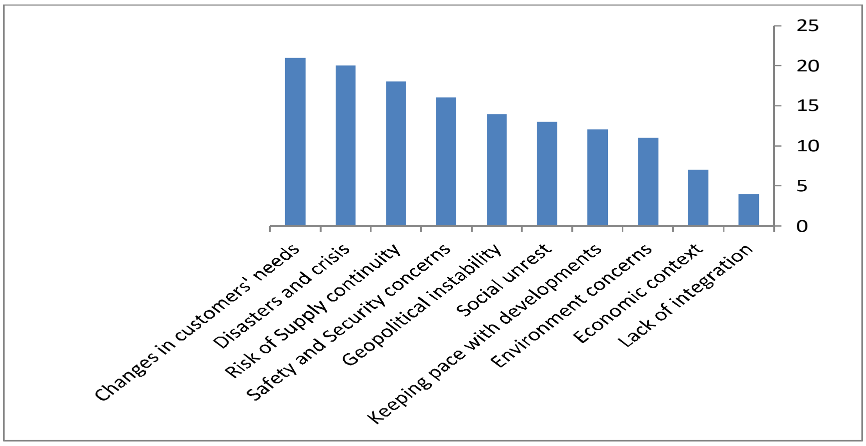

Figure 2 Rank of SCN sources based on respondents' answers

4 Framework for SCN in MENA region

In this section, a framework is developed to understand and analyze the supply chain nervousness in MENA region. MENA supply chain is part and strongly connected to the global SC. It effects and affected by the changes in the global supply chain like what happened during COVID19 pandemic crises. MENA SC chain has it is own conditions and is greatly affected by the never ended crisis in the region. The region is in the center of attention for many countries along with the political and social unrests which affect the SC performance and efficiency in the region. Therefore, MENA-SC is greatly affected by the SC nervousness. Nervousness in the MENA SC has some kind of unique characteristics due to the economic conditions, terrorists, piracy as well as the defense SC. The region is one of the largest consumers of weapons and defense equipment and the large weapon companies compete heavily in the Middle East market. In addition to the high number of partners, fierce competition, quick changes in demand, and a lack of environmental considerations, the lack of interest of logistic businesses in the region in sharing information with their chain partners, as well as delays in response and financial transactions, contributed to supply chain instability. This has a negative impact on costs, delivery times, and service quality between suppliers and consumers.

Figure 3 shows a framework of the nervousness in the supply chain of the MENA region. The framework consists of five major parts including nervousness sources and main causes, nervousness impact on the SC efficiency, and the noise factors that effect and affected by the SC nervousness, risk of uncertainty, and the suggested measures to deal with SC nervousness. The components of the framework are interconnected and interrelated, and are necessary to learn, explore, and understand the SC nervousness.

The sources of nervousness in the supply chain are classified into two main categories: the external sources of nervousness like natural disasters and manmade disasters and technological crisis, and the internal sources of nervousness like inside the organization and the global supply chain. Internal sources are considered the sources of nervousness within the global supply chain of the organization.

Nervousness causes could be internal like change in production plan, MRP system, change in requirements, BOM, inventory policy. The external causes of nervousness are out of the company control including the natural disasters or pandemic diseases. Based on the analytical study, the following summarize the main sources and causes of nervousness in the SC:

1. Changes in customers' needs and requirements. Customer demand is subject to change due to different reasons like change in market place, change in products, introduction of new technology, competitor's advantages (high quality, new tech, prices, advertisements), and prices change. This fluctuation in customer demand result in order deletion, decease or increase in order quantity. Customer demand change (new orders, order deletions, change in quantity, product return) make order decisions subjected to more frequent revisions affecting the systems throughout the SC. Also, error in demand forecast leads to frequent schedule change resulting in nervousness.
2. The necessity to cope up with emerging trends. Sometimes companies need to adopt new technology, software or hardware, to alter the product or add new features to stay competitive. Due to the introduction of new business trends, new technologies, shorter products life cycle, shorter product development cycle, environmental, and climate considerations, companies may need to respond quickly to survive which require change in their strategies, plans and decisions.
3. Supply continuity. The erratic and irregularity in the supply lead to decisions nervousness make it essential to ensure the continuity of supply and the availability of constituents/ components from suppliers. The sporadic supply of raw material, ingredients, components, parts, and subsystems from vendors interrupt the production schedule and require more frequent decisions. For example the supplies of agricultural crops are greatly affected by the season,

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disease, international demand, and global prices. The majority of MENA countries rely on the imported wheat form different sources resulted in a fluctuation of quality, quantity, and prices. Any disruptions can greatly affect the SC especially in the current complex, interrelated, and global SC. One of the most problems in MENA-SC is to stable network of vendors and supplier to assure the continuous supply. Sometimes suppliers change their processes which negatively affect customers. Supplier selection and partnerships is one of the essential factors for supply chain stability.

4. Geopolitical instability. MENA-SC is greatly affected by the political issues between countries both regionally and internationally. The countries in the region have no chance but to change their supply chain relationships and allies rapidly and directly once there is contrast between their policies, regardless of the obstacles and consequences, as what happened between many of the Gulf countries and Qatar in 2017. In addition, the region almost has a continuous presence of conflicts so that it is hardly to have a year without crisis or wars. Examples include what happened since 2010 and beyond of what's known as "Arab Spring" and the consequence disruptions of the supply chain in the region, where the need to search for new supply chains and new partners emerged as a result of the interruption of production and import and export limitations and stoppage in many countries such as Syria. Syria was one of the main sources of many goods and agricultural products to the region. For example, 60% of the volume of Jordanian trade exchange comes from or through Syria [24]. In addition to the terrorism that has prevailed the region and the world for a long period of time which has led to great challenges in dealing with some countries, companies and people.
5. Social instability. Arab spring is an example of how social issues and instability affect the market and was resulted from the protest of unemployed youth. The demographic and population dispersion effect the distribution of the products to the end-users. Social instability directly affects state economies, which are directly reflected in the supply chain, causing changes in plans and decisions. The social impact can be triggered at any moment as a result of a situation, high prices, violation of social customs, religious abuse, economic matters, unemployment, or political changes which negatively affect the performance and efficacy of the supply chain.
6. Economic context. Unexpected economic uncertainty impact the business, so it vital to keep updated of economic situation globally. This is because the changes in one country impact other countries like currency deflation and debt concerns. This assures the globalism of the SC. Changes like the increase in production, prices, taxes, customs, trade tariffs between countries, and border control restrictions complicate the trade and travel between countries. Inadequacy in SC infrastructure, outsourcing, efforts duplications, redundancy systems, and investment in wrong business are also cause economic instability. Today economy control the politics of the countries resulted in what so called trade war. Like what is going on between USA and China.
7. Disasters and crises. Disasters and crises are a major cause of internal and external changes, and the cause can be over the power of people (out of control or even prediction), of their making, or of things that humans have made, but controlling them outpaces their capabilities or requires enormous potential. Whatever the type of emergency, crises and disasters, it ultimately leads to an impact on the supply chain locally and internationally, causing a state of instability and contraction. There are some disasters that do not happen in the region and others that occur more frequently, such as dust storms. However, the region is characterized by many crises resulting from wars, displacement, refugees, famines, diseases and epidemics, terrorism, and political, social and economic instability, which directly affecting the supply chain, causing nervousness to MENA-SC.
8. Environmental concerns. Climate changes affect supply chain operations and activities like costs, performance, speed, transportation, responsiveness, shipping and handling, and quality resulting in major interruptions. Weather and climate like disasters are unpredictable which increase the difficulty of SCM and its processes. Heat waves, flood, cyclones, storms, extra rainfall, weather change, drought, decreasing snowfall, wildfire, and worming are resulting from climate change. These changes cause damage to the SC infrastructure, warehouses, streets, bridges, power generation plants, crops, etc. climate change cause a damage to raw material and natural resources like wild fire which destroy the forests and agricultural crops caused by heat waves and drought. This requires a quick reaction from the supply chain to changes in environmental requirements just like a change in user requirements.

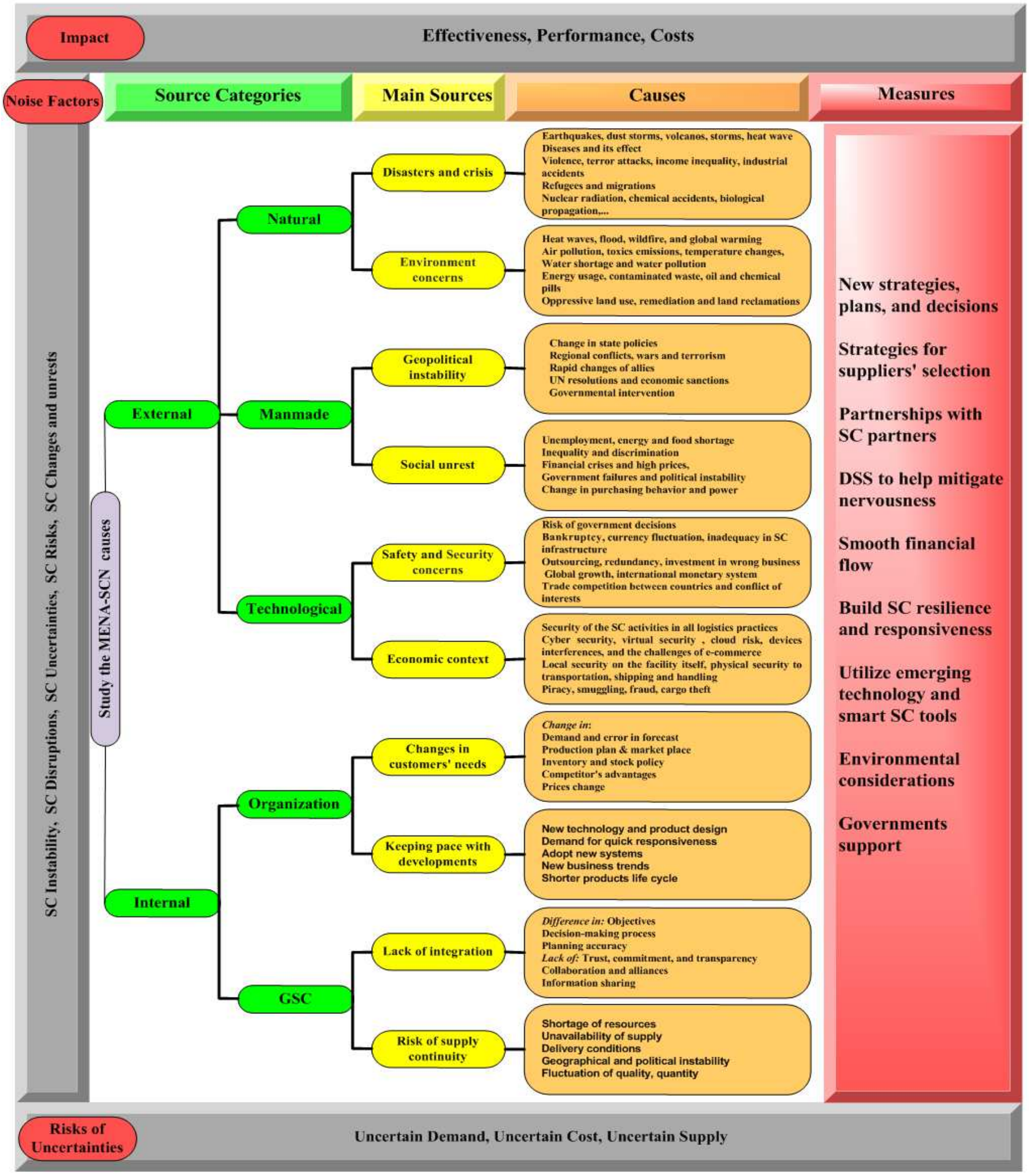

Figure 3 MENA-SCN framework

9. Lack of Integration. Partnerships and alliances are part of the SC competition; some make decisions regardless of their impact on others. The difference in planning accuracy between partners, decision-making process, lack of integration and overlapping interests, and how they handle risks lead to fluctuations and differences in plans and decisions. Lack of collaborations leads to lack of transparency in the SC decision-making system which adversely affect the trust among partners. Lack of desire to share data and knowledge leads to continuous change in partner plans and decisions causing the SC nervousness.

10. Security and safety concerns. The main threats include criminal statistics usage, production shrinkage, theft, terrorism, smuggling, piracy, IP loss, and intercepting of money transfer, competitor penetration, and goods imitating. Safety and security of the supply chain, including its physical and virtual risks affect all parts of the supply chain, including transportation, inventory, transported goods, common data, and the equipment used. Therefore, any security problem in the supply chain results in a change in the supply chain procedures, causing a kind of nervousness in the plans and decisions of the companies involved in the chain.

There are several noise factors that are effect the SC nervousness like SC instability, disruptions, uncertainties, risk, changes and unrest. These factors require regular rescheduling of orders in terms of setup and quantity to constantly respond to varying demand requests, where a necessary trade off among responsiveness, cost, and instability occurs. They results in change and frequent rescheduling of orders in terms of timing and quantity requiring frequent rescheduling activities. Instability is present even with stable demand. Undesirable effects of noise factors iclude ıncreased production and inventory costs, ıincreased in throughput times, reduced productivity, decrease in capacity utilization, lower customer service levels, confusion on the decision making system, loss of confidence to planning system, low morale, etc.

The risk of uncertainity is considered the one of the main root and sources of supply chain nevousness. The principal risk of SC uncertainity come from the uncertain demand, cost, supply. Therefore special attention should be paid to these factors in the SC strategies, policies, and planning.

SC managers should take several measures to reduce the impact of SCN. These measures may include new strategies, plans, and decisions, strategies for suppliers' selection, partnerships with SC partners, developed decision support systems to mitigate nervousness, smooth financial flow, build SC resilience and responsiveness, utilize emerging technology and smart SC techniques, consider environmental factors, and seek the governments support to minimize the impact of their decisions.

Organization should seek the continuity of their SC in case of crises such as the wake of COVID19 pandemic. It is important to know when and where the disruption will occur and how countries will react. The most important thing is the guarantee the continuity of the SC during and beyond crisis. Therefore, organizations and their SCs partners need to constantly reviewing the politics, regulations, and technological changes to avoid the risk of inability to supply products. SC partners are required to share information to increase visibility and resulted in unity SC decisions. For success business, enterprises need to integrate SC and business, technologies, employees, and the decision making systems.

SC-Security should be a high priority to firms and should cover all SC activities and functions like transportation, shipping and handling, and all logistics practices to eliminate any disrupt of the operations. The main objectives of SC security should be to recognize, evaluate, prioritize, and provide solutions to SC risks and nervousness. There should be a balance in relationship between human, environment, and industrial revolution to face the dramatic increase in the earth population, and the high rate of consumption and reduction in natural resources.

5 Delphi-AHP tool

The Delphi method is used to obtain data from a panel of experts sequentially through structured questionnaires. It is a very practical way to achieve a convergence of opinions. To obtain generally reliable results, studies have shown that at least ten experts are sufficient [24]. A total of eleven experts were used in this study to obtain reliable results. All experts have more than 15 years of experience in supply chain areas. To identify the most prominent SCN causes, a Delphi technique was performed in three rounds. The experts were asked to confirm the main source causes, sub- causes, and sub- causes at three levels in the hierarchy. The experts were asked to add or eliminate SCN causes in the model presented to them.

Once selecting the causes of SCN, AHP is used to prioritize the causes. AHP is a widely used and practical method of pairwise [25] and is suitable for ranking variables and modularizes a problem [26]. AHP approach was used to evaluate different variables [27], asses SC risk drivers [28], and to calculate the decisions of outsourcing location on SC resilience [29]. The AHP methodology used in this study include the following steps:

1. Outline the research objective. The research objective is to study the MENA region SCN factors including sources and causes.
2. Form the hierarchical structure. The hierarchical structure created was shown to and confirmed by experts using the Delphi method.
3. Develop the pairwise comparison matrices. Pairwise comparison matrices are built for all levels of causes. A questionnaire was formed using 1 to 9 scale to collect data from experts on paired comparison matrices for all SCN sources and causes.
4. Determine the priority weights. The eigenvalues and the eigenvector are calculated for the pairwise comparison matrices developed for SCN causes and sub-courses.
5. Examine the consistency ratio. Check the consistency of the pairwise comparison matrix using the following equations: $\lambda_{max} = average\ (AxX/X)$, where X is the priority vector and a pairwise comparison matrix, consistency index $CI = \lambda_{max} - n/n - 1$, the consistency ratio $CR = CI/RI$, RI is a random index based on matrix different sizes.

In this study, a framework for the SCN Assessment was proposed and SCs from the MENA region were selected to provide a case application of this tool. Thus, it is imperative to identify the SCN causes. The Delphi-based AHP approach has certain advantages over AHP-based interviews as it is free from prejudice and data acquisition through iterations improves data quality and stops when data saturation is reached. The hierarchical model of SCN causes is as described in Figure 3.

6 Discussion of Case Application and results

Twenty four enterprises from MENA region were taken for this study. As a result, significant organizations from two different continents (Asia and Africa) expressed a strong desire to use the SCN tool. Consequently, eleven senior experts agreed to participate in the research study. The experts were selected based on their experience and knowledge. These eleven executives and managers provided decision-making hierarchy data to refine the SCN tool, and we then collected data in paired comparison matrices from these experts. The executives' above responses are then converted into sharp scores according to the AHP scale to calculate the weights per AHP [30].

A three-stage research methodology was used for data collection and analysis. In stage one, a list of SCN causes were identified and selected from the literature search and survey results; Stage two, determined the most relevant causes with the help of business experts. The experts refined the causes into a three-level hierarchical level model. This goal was achieved through a Delphi method. In Delphi, three iterations were enough to achieve the data stability in responses; Phase three, SCN causes were classified using the AHP method. In level one five main source causes of SCN in MENA region were identified, level two determine the ten secondary causes, and level three conclude the fifty causes at the lowest level. Figure 3 shows the hierarchical SCN model after three rounds of iteration.

After that, we calculate the priority vector for each level SCN causes using the AHP method. The pairwise comparison matrix for the main causes is shown in Table 2. The calculations of the consistency index and ration, λ_{max} = 5.270; CI= 0.22; CR=0.06 <0.1, indicate the consistency of the matrix. The paired comparison matrix for causes was structured similarly. The priority vector was calculated for each matched comparison matrix and the consistency ration is acceptable as CR<0.1.

Table 2 Pairwise Comparison matrix for main SCN sources

Goal	Natural	Manmade	Technological	Internal	Normalized principal eigenvector
Natural	1	2	3	5	36.24%
Manmade	1/2	1	2	4	25.16%
Technological	1/3	1/2	1	1	9.03%
Organizational	1/5	1/4	1	1	6.07%
GSC	1/2	1/2	3	7	23.49%

The overall weight of each subcauses was calculated as shown in Table 3. Diseases and its effect have the highest weight (0.081) when presenting the classification of the selected causes. Violence, terror attacks, income inequality, industrial accidents ranked the second highest with a weight of (0.065); refugees and migrations ranked third (0.055); Regional conflicts, wars and terrorism ranked fourth (0.054), and Governmental intervention and political instability ranked the fifth (0.054). This means that these subcauses are the major driving forces to the SCN in MENA regions. The first three with the highest ranks are part of the disasters and crises while the fourth and fifth subcauses are part of the geopolitical instability. Adopt new systems ranked the lowest (0.0008). This suggests that decision makers should pay more attention to SC external factors when assessing MENA-SCN systems.

The priority vector for the SCN causes at level 3 the relative importance of the SCN sub-causes was obtained. These partial drivers can be mitigated in practice using proper solutions. SCN measures are practical solutions that can be used directly to reduce the impact of partial SCN sources.

The results are helpful for supply chain professionals to get a well advice of the nervousness of their SC and provide information to understand which factor plays a larger role in nervousness. The results explore the factors increase risk if the unknown occurs, and how sensitively SCs react to such interruptions. Research results on the SCN business causes rankings show that most of external causes are in the top twenty in the SCN involvedness category.

The results of the analysis described above should be considered by both SC managers and executives in the current Covid-19 consequence to implement mitigation strategies and close the missing links in SCs. Identifying the root causes of the SC weakness would help strengthen the SC. Nervousness can be controlled by reducing the complexity of the supply chain. This could be achieved by improving the transparency and integration with new SC strategies, utilizing emerging technologies, government support and building new SC resilience.

Table 3 Ranking of SCN sources in MENA-SCs

Level I	Weight	Level II	Weight	Level III	Weight	Global Weight	Global Ranking
Natural	0.362	Disasters and crisis	0.72	Earthquakes, storms, volcanos	0.14	0.03652992	7
				Diseases	0.31	0.08088768	1
				Violence, terror attacks, inequality	0.25	0.065232	2
				Refugees and migrations	0.21	0.05479488	3
				WMS propagation	0.09	0.02348352	17
		Environment concerns	0.28	Heat waves, flood, wildfire	0.24	0.02435328	14
				Water shortage and pollution	0.27	0.02739744	11
				Air pollution, toxics emissions	0.3	0.0304416	9
				Energy usage, contaminated waste	0.15	0.0152208	24
				Oppressive land use	0.04	0.00405888	44
Manmade	0.252	Geopolitical instability	0.67	Change in state policies	0.14	0.02360008	15
				Conflicts, wars and terrorism	0.32	0.05394304	4
				Rapid changes of allies	0.08	0.01348576	29
				UN resolutions and sanctions	0.14	0.02360008	16
				Governmental intervention	0.32	0.05394304	5
		Social unrest	0.33	Unemployment and food shortage	0.27	0.02241756	18
				Inequality and discrimination	0.17	0.01411476	28
				Financial crises and high prices,	0.18	0.01494504	26
				Government failures and political instability	0.12	0.00996336	35
				Change in purchasing behavior and power	0.26	0.02158728	19
Technology	0.090	Safety and Security concerns	0.58	Risk of government decisions	0.29	0.01518846	25
				Bankruptcy and currency fluctuation	0.09	0.00471366	42
				Outsourcing and redundancy	0.27	0.01414098	27
				Global growth and system	0.15	0.0078561	38
				Trade competition	0.2	0.0104748	33
		Economic context	0.42	Security of the SC activities	0.27	0.01024002	34
				Cyber and virtual security	0.34	0.01289484	30
				Challenges of e-commerce	0.08	0.00303408	46
				Local and physical security	0.17	0.00644742	39
				Piracy, smuggling and cargo theft	0.14	0.00530964	41
Organization	0.061	Changes in customers' needs	0.81	Change in demand	0.41	0.02015847	22
				Change in Production plan	0.12	0.00590004	40
				Change in Inventory policy	0.07	0.00344169	45
				Change in Competitor's advantages	0.22	0.01081674	32
				Change in prices	0.18	0.00885006	37
		Keeping pace with developments	0.19	New technology and product design	0.37	0.00426721	43
				Demand for quick responsiveness	0.25	0.00288325	47
				Adopt new systems	0.07	0.00080731	50
				New business trends	0.17	0.00196061	48
				Shorter products life cycle	0.14	0.00161462	49
GSC	0.235	Lack of integration	0.62	Difference in objectives	0.22	0.03204036	8
				Difference in DM process	0.26	0.03786588	6
				Difference in planning accuracy	0.14	0.02038932	21
				Lack of trust and commitment	0.2	0.0291276	10
				Lack of Collaboration and alliances	0.18	0.02621484	12
		Risk of supply continuity	0.38	Shortage of resources	0.22	0.01963764	23
				Unavailability of supply	0.24	0.02142288	20
				Delivery conditions	0.14	0.01249668	31
				Geographical and political instability	0.29	0.02588598	13
				Fluctuation of quality, quantity	0.11	0.00981882	36

7 Conclusion

This research explore the nervousness of the supply chain in MENA region in terms the SCN sources, main causes, noise factors, risks of uncertainty, impact, and the measures to mitigate the SCN. To this end a survey is developed and distributed to companies in the region and a group of experts are utilized to identify the major causes of SCN, study their impact, analyze the measures, and group the causes in main and subcategories. Based on the analysis, a framework was introduced to understand and investigate the SCN in MENA regions. The results indicate the nervousness sources and causes and rank the cause based on their impact. Existence of SCN even in the most stable SCs necessitates the exploration of the required measures to reduce the effect of nervousness. A list of measures is proposed to decrease the SCN and improve competitiveness, effectiveness, and future SC resilience.

As part of the global supply chain, MENA-SC suffers from nervousness with special characteristics. Nervousness in SCM systems is thought to be a source of confusion, instability, or uncertainty in SC systems due to disruptions or unexpected decisions. Nervousness increase, potentially due to the frequent change in the decisions, more frequent change in decisions lead to a confusion for both workers and customers resulting in a reduction in trust, moral, and loyalty to the SC system. Nervousness increases the bullwhip effect, pushing SC to strengthen the buffer against frequent decision changes. When all of these elements are considered, anxiousness might result in a high level of discontent. As a result, system nervousness should be considered because it has a good or negative impact on the entire SC, typically at the same time for different SC partners and locations.

Supply chains have become more nervous in recent years. Understanding SCN has become essential for SC-managers in times of high uncertainty, as Covid 19 further explains this situation. Decision makers in MENA countries should rethink of the design of their SCs from a nervousness perspective. Therefore, this research adds to the literature on SCN by evaluating SCN factors such as causes, impact, and measures. This research identified five main categories and fifty operational causes. These SCN causes can be reduced and managers can take action to reduce the negative effects of disruption. Supply chain disasters and crises, geopolitical instability, and social unrest were found to be the most significant factor.

The results of the study help industrial managers, practitioners and decision-makers to focus on the SCN considerations during the planning stages, to increase sustainability in MENA supply chains, and further advance corporate and supply chain resilience development. The framework may also serve as a theoretical construct for a future empirical study on sustainable supply chain innovation in the manufacturing sector. Furthermore, the study introduce many policies and strategies to reduce nervousness in the SCs. Nervousness solutions may include integration, dealing with the problem from an external perspective, coordination's with partners, customers, and suppliers, and reduce instability in production environment.

This proposed SCN framework could be used to conduct surveys in different industries or consider the global supply chain (GSC) nervousness, and it would also provide interesting information and attention to GSC managers that require immediate attention. To capture the ambiguity of data collection by experts, advanced techniques such as Fuzzy-AHP technique can be used. This research can help companies decide strategies to reduce nervousness in the SCs, and would lead to a better assessment and decision on future resilient supply chains.

Future studies should examine the causes that lead to the occurrence of nervousness in the supply chain, methods of measuring it, and the appropriate solutions. Additional research may focus on evaluation of the nervousness solutions and use multi criteria decision making (MCDM) techniques to analyze and rank order the solutions based on their priority of implementation. Further research should deal with the nervousness in the global supply chain in terms of causes, sequences, measures, and solutions; so that decision makers can benefit from it in light of globalization, disruptions and instability in the supply chain, which ultimately leads to sustainable SC and increases the future resilience, responsiveness, and competitiveness of the SC.

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WAYS TO EFFECTIVELY ADDRESS PROBLEMS EXISTING IN THE URBAN PASSENGER TRANSPORT SYSTEM

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Keywords: bus, efficiency, passenger traffic, urban transport, industry standard.
Abstract: At present, public transport needs to be managed using the different models, which will take into account health problems, passenger transport problems, refinement of technical parameters of buses and their adaptation to urban operating conditions, which would be one of the preventive measures in the context of combating the coronavirus pandemic. The article discusses the issues of optimizing the routeing scheme of buses and minibuses in the conditions of a three-level transport network in large cities. Measures for the performance of the city bus routes have been developed. It has been established that the qualification of a driver and the selection of urban passenger vehicles are central issues in terms of fuel efficiency and reducing the number of harmful substances in exhaust gases.

1 Introduction

One of the fundamental conditions for the socio-economic development of the country is the effective functioning of the transport system equipped with modern technologies.

Starting from the second half of the twentieth century in the world, including Georgia, we are witnessing the process of intensive motorization. The increase in the number of vehicles has resulted in two pronounced and contradictory trends. In particular, the high level that motorization has reached predetermines the development of the economic potential of society and ensures maximum satisfaction of the transport needs of the people [1,2]. On the other hand, it has contributed to the increased magnitude of the negative impact on society and the environment, which has resulted in environmental degradation.

Today, the problem of the rational use of our country's fuel and energy resources has acquired special economic significance because Georgia is one of the countries whose motor transport consumes only imported fuel and energy resources.

As oil and oil-origin fuel reserves are not renewable, and sooner or later, these reserves are expected to be exhausted, but the number of vehicles in the country is growing at a rapid pace, and the problem of fuel economy of vehicles continues to be a priority.

A successful resolution to this problem will depend on the level of perfection of automobile designs and scientific and technological progress in searching for and using alternative fuels in motor transport.

Today, addressing the transport problems through the improvement of technical parameters of vehicles is not having a great effect. It is necessary to explore the issues related to the theory of travel service administration and vehicle traffic, that is, to review the issues of the transportation process management itself under conditions of rapid motorization. Therefore, there has recently been a growing interest of researchers in the urban transport system, and the theories of passenger traffic simulation have been created. They are aimed at improving road infrastructure and creating systems of quality passenger service [3].

1.1 The major components of the system of urban passenger transport

In large cities, there are numerous routes providing transport for passengers. Acquisition of specific information on these routes (provision of reliable data on passenger flows and distributing them according to day and night hours and days of the week) is further processing, selection of the optimal route, and the number of vehicles (buses, minibuses) should be carried out systematically, taking into account the context combating the coronavirus pandemic**.**

In order to solve this problem, it is necessary to study the urban routes, analyze the operating parameters, process the information obtained from the experiments and provide sound guidance. This methodology will allow us to calculate the real parameters for a particular route and thereby increase the performance effectiveness of vehicles. It is necessary to take into account the volumes of traffic and passenger flows, as well as the operating characteristics of vehicles. In view of the foregoing, the definition of operation parameters on urban bus routes should be based on the establishment of characteristic parameters of these routes taking into account passenger flows, which will eventually improve the quality of passenger services and increase the efficiency of the transport process [1,4].

The best rational option is considered that perfectly meets the needs of the population and high rates of passenger transport in terms of environmental performance and the minimum risk of coronavirus spreading.

The route and vehicle driving on this route should meet the major requirements. In particular, they must: be adequate to the volume of passenger flow; have sufficient manoeuvrability and a rapid response capacity to the volatility of flows and the disruption to traffic; be coordinated with other types of urban passenger transport; be correctly adapted to the length of flow, direction, and time, as well as to the rational distribution of terminal and intermediate stops.

A step forward in this regard is the introduction of a three-level transport network. The first level is the 10 main corridors, where passenger flow is large and passes through all the main big streets and avenues of Tbilisi. It is fed by two additional types of corridors - the second and third-level lines, respectively - the so-called "city lines" for traffic between the blocks, the so-called "block lines".

2 Methodology

2.1 Designing the passenger transport system development programs

As we have mentioned, the main goal of the urban passenger transport system is to ensure the qualitative, timely and cost-effective displacement of the population with a minimum level of coronavirus spreading and with minimum environmental pollution. In this regard, one of the most important is the qualification of a driver, which depends on the economical methods of bus driving and increases the efficiency of the transport process [11].

2.2 Studies of the city route operating parameters

We have conducted a research investigation on the operational parameters of the intracity line by involving the drivers with varied work experiences and levels of qualifications [22]. The results of the experiments that reflect the influence of driver's qualification on the operational parameters of a bus are given in Table 1.

Operating indicators	Operating conditions	Drivers with work experience of less than 1 year	Drivers with work experience of more than 5 years
Average speed, km/h	Urban	30	31.7
The number of stops, km^{-1}	Urban	1.55	1.5
Fuel consumption per line	Urban	24.7	24

Table 1 The influence of driver's qualification on the operational indicators of a bus

2.3 The review of the experiment

Following analysis of our experiment, we can conclude that during the operation of the bus on the city route, which runs on the first from the three-level transport network, that is, on one of the 10 main corridors, on a special bus line, in the case of drivers with different amounts of experience, the difference between the average speeds of traffic does not exceed 5%. This proves that even under conditions of rapid growth in traffic flows, the average speed of the bus is practically determined by a driver and not by the traffic flow, and it is almost the same for drivers with different amounts of experience on the city route [4,5,22].

The difference between the costs of line fuel reaches 2.8%, and it practically does not depend on the qualifications of a driver [8].

A very important factor is the impact of the number of stops on the performance of buses. However, as can be seen from the analysis of the values given in the table, in the case of drivers with different amounts of experience on the city routes, the difference between the values of specific quantities of stops is small and reaches just 3% [9,10].

The analysis shows that in the case of the special bus lane, the performance indicators do not depend on the qualification of a driver, which should be taken into account by transport companies in general in order to increase efficiency. On the second-and third-level lines, on the other hand, the qualification of a driver is of high importance. In the case of drivers with different amounts of experience, the qualifications of a driver, particularly his driving style, impact operating parameters – fuel consumption by rolling stock, environmental safety and the efficiency of a transport company in general [6].

It is necessary to retrain drivers with a fuel-saving criterion, and it has been computed that through retraining drivers in the motor transport enterprise, it is possible to achieve greater fuel economy.

It is known that the energy of rolling stock, in terms of phases and the amount of fuel consumption, correlates with the number of stops. The study showed that allocating a special line for buses, reducing the number of stops and increasing the runway length led to a reduction in fuel consumption, which is less dependent on the qualification of a driver. This leads to a reduction in the number of exhaust gases, which improves the environmental safety of road transport. Therefore, one of the main factors that do not affect the operating cost of rolling stock fuel and environmental safety is the qualification of a driver [7,9].

One of the main ways to reduce fuel consumption and increase its environmental friendliness, is proper organization of the transport process and improvement of management. Through improvements in science and technology, it would be possible to ensure efficient fuel consumption. Fuel consumption depends on the following conditions:

- Operating conditions.
- Technical condition of vehicles.
- Organizational–technical measures.

For its part, each of these conditions also depends on a number of factors. For example, fuel economy depends to a large extent on road conditions, traffic modes, weather conditions, seasonality and so on. Allocating a special line for buses is a step forward in this regard.

An example of the effect of a vehicle's operating cycle on the operating cost of fuel (frequency of stops) can be the relationship between fuel consumption and long-distance travel. Cyclicity of operating modes leads to disruption of the established thermodynamic processes in the engine, increases fuel consumption and reduces power. This is proved by the experimental results. This is illustrated by the experimental data on the increase in fuel consumption by the road transport moving on the second and third-level lines of the city by 10-15% compared to the transport moving outside the city, while for buses moving on the first-level lines, this margin is within 5-7%.

An analysis of numerous studies revealed that one of the most important factors affecting fuel consumption is road conditions.

The variable nature of road conditions is taken into account when adjusting the norms and standards of technical operation of vehicles. At the same time, operating conditions have an impact on the operation mode of the vehicle. In accordance with the state of the road surface, fuel consumption may vary by 15-20%. In this regard, the existence of the first three-level transport network is a step forward. The rational organization of road traffic allows for reducing fuel consumption by 15%.

Fuel consumption in cities is affected by the presence of regulated and unregulated intersections on the route and their number, the presence of road signs, correct markings and so on.

The influence of the factors acting on the fuel consumption along with the operating properties is manifested in the formation of the operating modes of rolling stock.

The gains in productivity of urban passenger transport would be achieved through the reduction in fuel consumption, which is based on the management of the operating fuel costs of buses. In order to develop the mentioned measures, it is necessary to collect data on fuel consumption for each city bus route and to provide their computer processing. Based on the analysis of the obtained data, the decision is taken on the need to adjust the operating fuel costs and for adopting the route standards.

This will improve the efficiency of urban motor transport companies on the basis of the route standards of fuel costs by adjusting the existing standards of fuel consumption of buses.

Equally important to enhancing the efficiency of passenger transport and the successful functioning of the transport process is the correctly chosen city route. The main goal is to provide transport of passengers in the shortest possible timeframe. Experience demonstrates that the transport network routing in major cities is a very complex and ambiguous process [14,15].

2.4 City route choice

Equally important to enhancing the efficiency of passenger transport and the successful functioning of the transport process is the correctly chosen city route. The main goal is to provide transport of passengers in the shortest possible timeframe. Experience demonstrates that the transport network routing in major cities is a very complex and ambiguous process.

Proper planning of stops on the city route is of high importance.

The calculation of the operating parameters of the bus routes and the provision of rational organization of passenger transportation should be based on the study of the actual passenger flow on the route.

The aim of the research is to obtain reliable data on the passenger flows on the bus routes and to distribute them according to the hours of the day and days of the week, which allows us to rationally organize the work on the bus lines, to establish their timetable, to choose the type of rolling stock, and to distribute the vehicles [12,13].

The study of passenger flows can be complex and selective [18]. Different methods are used for passenger flow study: surveys, questionnaires, coupons, visual methods and so on. A traffic flow study is also possible through the analysis of revenue from a particular route by the number of tickets sold during the transportation of passengers [19,20]. The information received on passenger flows is processed by specially designed programs using computer technologies.

The information obtained as a result of transportation of passengers must be redistributed according to the hours of the day and the stops on the route. It is schematically represented by diagrams. The diagrams allow us to visualize the distribution of passenger flows in each direction on the route at certain times of the day, as well as the values of passenger flow at "peak" hours, according to which the maximum number of buses is determined. The diagrams have been constructed using the day-to-day flow distribution tables (Table 2).

The distribution of passenger flows in both directions of one of the routes of the city (№14) according to the hours of the day is given in the table, and the diagram is shown in Figure 1.

Table 2 Distribution of passenger flows on the urban bus routes in both directions by day-night hours

Distribution of passenger flows by day-night hours					
Day-night hours	Number of passengers		Day-night hours	Number of passengers	
	Direction			Direction	
	Forward	Backward		Forward	Backward
5-6	45	21	14-15	370	374
6-7	455	483	15-16	382	420
7-8	591	562	16-17	440	575
8-9	692	722	17-18	577	547
9-10	623	421	18-19	741	605
10-11	505	310	19-20	363	421
11-12	301	173	20-21	192	222
12-13	240	204	21-22	70	51
13-14	466	155	-	-	
				7053	6266
				13319	

Distribution of passenger flows in both directions on the city bus routes

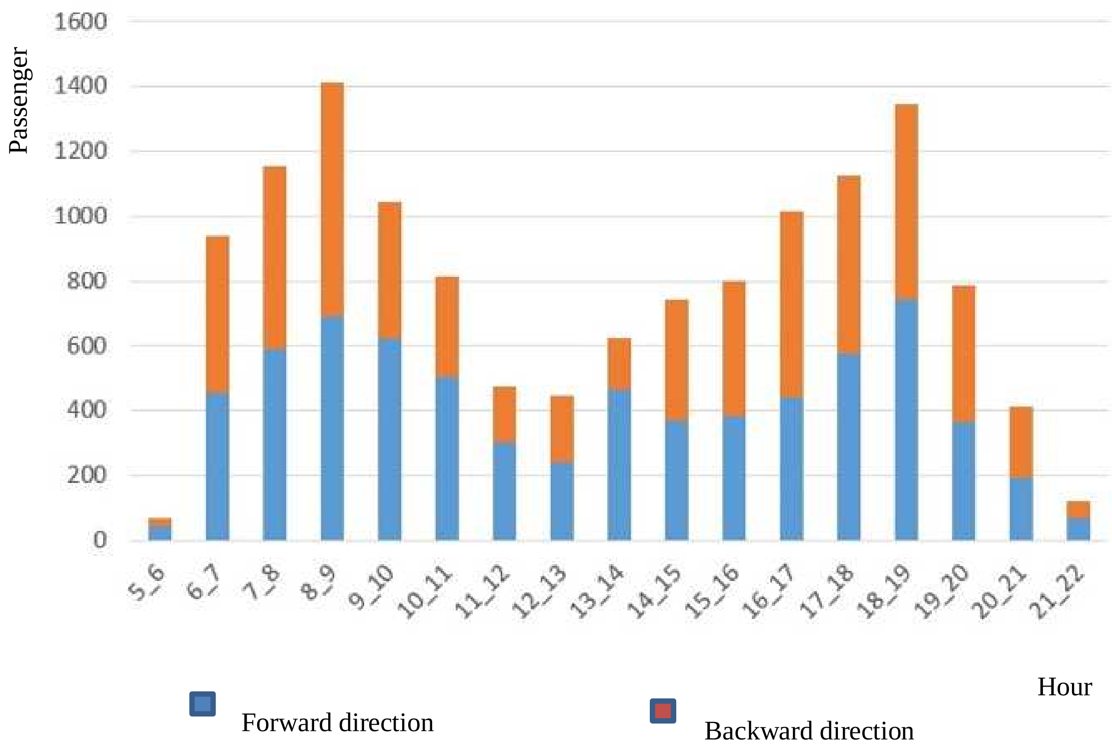

Figure 1 Schematic distribution of passenger flows to the hours of the day and the stops on the routes in forwards and backwards directions

As can be seen from the diagram, the maximum values of passenger flows on a given route are 8-9 and 18-19 hours. As a result of the adjustment of road infrastructure, it is estimated that all the ten first-level lines of the city will increase passenger flow by 1.5-2 times, so the maximum number of buses should be calculated according to passenger flows at these hours. During the remaining hours, the number of buses on the route should be redistributed to ensure timely, safe and comfortable passenger services.

Thus, the analysis shows that in order to effectively organize the traffic of urban passenger vehicles and to determine their optimal number on specific routes, it is necessary to establish the patterns of change in passenger flows. Analysis of the various methods of passenger flow study allows us to select any of them according to a specific purpose, which will provide efficient passenger transport services.

A modern type of bus produced by leading companies with a large capacity (90 seats, 12 m long) was selected.

In order to determine the fuel efficiency and environmental friendliness, the operation study was conducted on several city routes in Tbilisi.

The data of the conducted operation experiment were processed using computer technologies, and the numerical values of some important parameters are given in Table 3.

Table 3 Some operating parameters of routes

Parameters	Arbitrary notations	Route number			
		N 150	N 14	N 47	N 54
The length of the route, km	L	13.3	8.1	13.5	11.9
Specific quantity of stops, km^{-1}	N_0	1.95	1.97	1.92	1.93
Specific quantity of light signs, km^{-1}	N_L	2.7	3.1	2.8	3.3
Specific quantity of stops near the light signs, km ^{1}	N	0.9	0.98	0.96	1
Operating speed, km h	V_S	20.1	17.5	22.2	19.7

Analysis of these data showed that the length of the route has a significant impact on the effectiveness of the vehicle's environmental safety, and if it is reduced, fuel consumption increases while traffic speed decreases. This is explained by the increased number of stops (N_0, km^{-1}). In the case of the short-distance routes, it almost doubles, and this result confirms the correctness of what we have said above.

A step forward in this regard is the regulation of road infrastructure, which envisages the creation of a special line for buses. The example of Tbilisi City shows that all the ten first-level lines belong to congested areas, and the creation of special bus lines on them will lead to a partial reduction of traffic congestion; timely transportation of passengers and increased passenger flows by 1.5-2 times; obvious improvement of environmental conditions, which is manifested in the reduction of the number of stops, the number of traffic lights and the number of stops with traffic lights, an increase in the route length, and an increased operating speed.

2.5 Passenger traffic route profitability

The cost-effectiveness of passenger transportation largely depends on the correct selection of rolling stock. First of all, before choosing a rational-capacity bus, it is necessary to remember that buses are classified according to two major criteria - destination and capacity. During urban passenger transportation, urban and large-capacity buses are regarded as a preferred solution [21].

An important parameter is the capacity of the bus, which primarily affects the bus filling factor and the comfort of passengers. When determining this factor, the values of passenger flows (in one direction) and their unequal distribution according to the hours of the day and night should be taken into consideration. Under the current conditions, in the context of combatting the coronavirus pandemic, there was a significant reduction in the bus filling factor, and its value was 0.5. In this regard, it is necessary to make some changes in the industry standard.

With improving the road infrastructure, according to the existing methodology, the bus was selected according to the existing methodology, and the bus traffic interval, frequency and all the necessary parameters were determined.

The number of public transport and the location of stops were theoretically determined according to the major indicators, according to the distance travelled by pedestrians and the speed of public transport [16,17].

Finally, we can conclude that in the current environment, in a manner fully consistent with the standard and for people with disabilities, the requirements are met by large-capacity buses at peak hours at intervals of 3 minutes, while during off-peak hours - by the withdrawal of buses.

Thus, the analysis shows that the efficient operation of the city bus routes is influenced by a large number of factors, the maximum account of which ensures safe, quality and timely transportation of the population.

3 Result and discussion

The analysis allowed us to systematize and generalize the efficiency criteria of urban passenger transport companies, identify indicators that characterize the quality of transport services for the city population, as well as the performance effectiveness of transport companies and the specifics of routes.

In order to select the appropriate urban passenger vehicles for the specific routes, as well as to determine their optimal number, the patterns of variability of passenger flows and the distribution of the number of vehicles selected on their basis according to the hours of the day were established.

The article analyses and establishes the operational factors affecting the fuel efficiency and environmental safety of road transport and focuses on qualification of a driver and the effective methods of driving to ensure the efficiency of the transport process.

It has been established that when creating a model for managing the urban passenger transport system, it is advisable for the municipal government to maximally investigate the city population's demand, study passenger flows and establish routes and timetables, as well as provide the timetable monitoring and scheduling system.

There has been established the nature of the variability of the operating parameters (average speed, fuel consumption, etc.) during the operation of buses in urban conditions, which is due to frequent stops, high saturation of obstacles, and increased frequency of unsteady traffic modes, and so on. As a result, there has been justified the need to improve the professional skills of drivers to increase the effective performance of transport companies and use the methods of their material incentives.

In urban traffic, the number of stops per kilometre of the route is large, which increases the share of unsteady bus traffic on the line, resulting in a significant increase in fuel consumption, increasing emissions and deteriorating environmental conditions in the city. A step forward in this regard is the improvement of road infrastructure, which envisages the construction of ten first-level roads in the city with special bus lines that will pass through all busy areas or streets of the city, thereby extending the bus lines and reducing the number of intermediate stops.

In terms of increasing the productivity of transport companies, it should be noted that, using the example of Tbilisi city, road infrastructure has been conditionally divided into two parts, the first of which, which includes ten first-level sections, has less dependence on qualification of a driver, the driver's choice of economy modes, namely, on his driving style, the reduction in the number of stops automatically led to the reduction in fuel consumption, it is no longer necessary to train drivers on the criteria of fuel efficiency.

The nature of the variability of its performance indicators in the vehicle's operation process in the conditions of Georgia has been established, which is due to frequent stops, high saturation of obstacles, increased frequency of unsteady traffic modes, and so on. As a result, with a view to improving fuel efficiency and environmental friendliness, there has been justified the appropriateness of motor vehicles.

The studies that we conducted on the urban route operating parameters and the results of the experiments involving the drivers with different amounts of experience and qualifications when driving on different categories of roads and in various transport network conditions show that the effective performance of transport companies varies between 55-60% depending on the qualification of a driver.

As can be seen from the analysis, it would be wrong to suggest that the economical driving of the vehicle is associated with the average speed of traffic and, consequently, with the reduction in the transport work performed. Therefore, when operating in these typical conditions, the driver's ability to maintain the optimal operating modes of the vehicle in terms of fuel economy comes first.

4 Conclusions

The article discusses and elaborates the measures of operation of city bus routes in the conditions of a three-level transport network in big cities, thus ensuring timely, safe and comfortable service of passengers, in a relatively ecologically clean environment, with minimal economic costs.

- The regularity of the change of passenger flows has been established.
- The bus scheme of minibuses and minibuses was optimized.
- Urban passenger vehicles were selected, and their optimal number was determined.
- The number of vehicles was distributed according to the day and hours.

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