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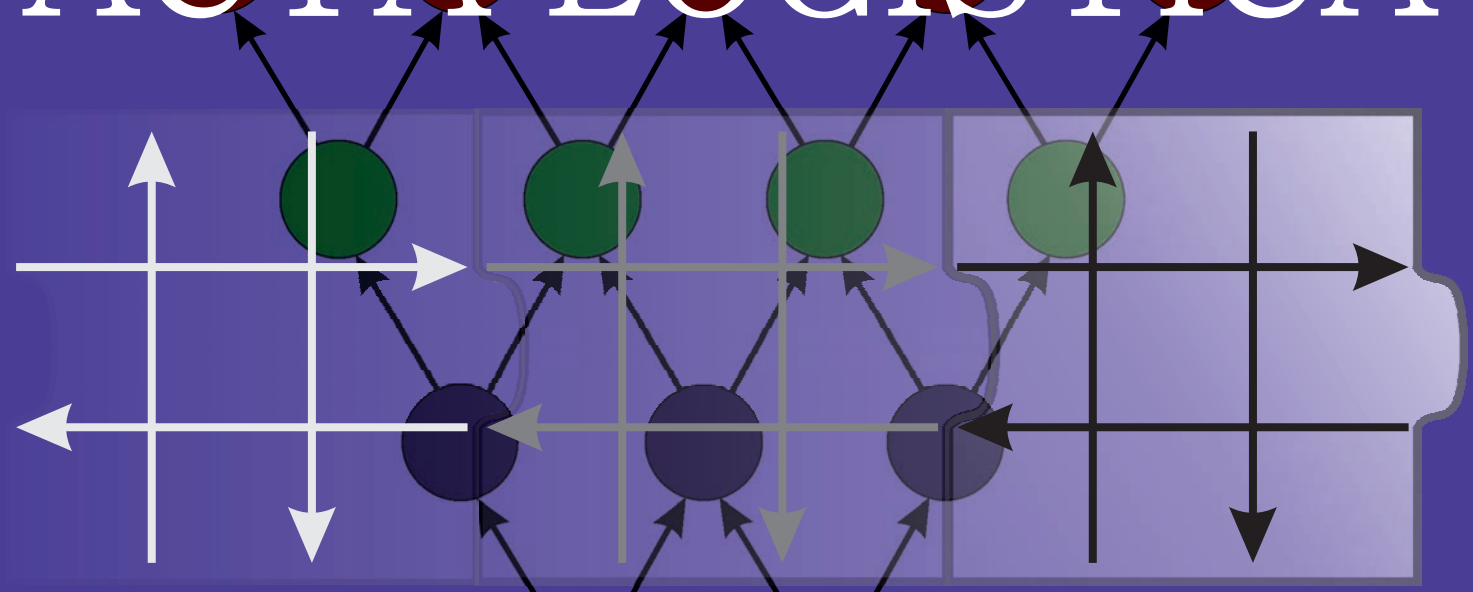

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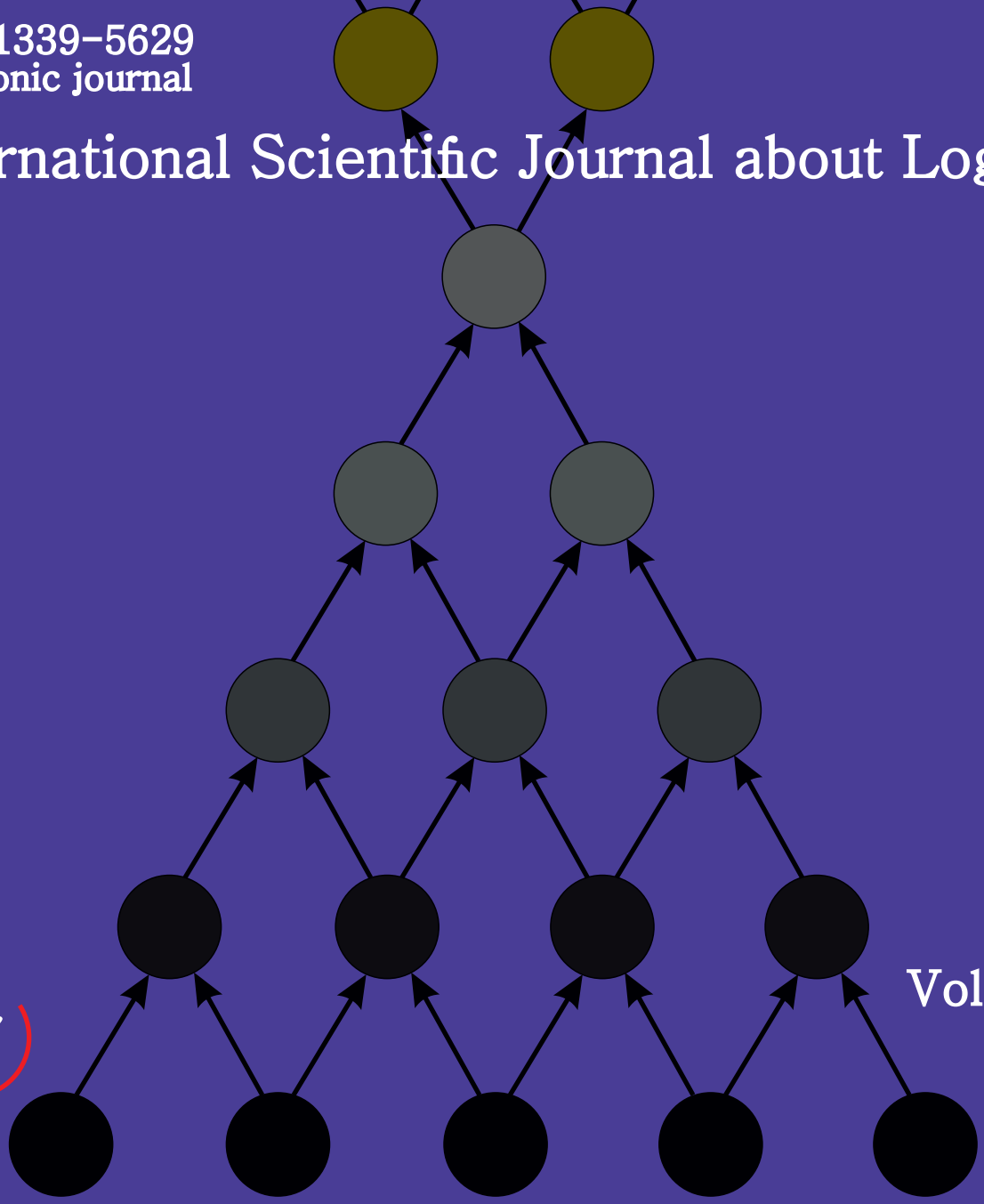

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Exploring the effects of perceived values on consumer usage intention for electric vehicle in Thailand: the mediating effect of satisfaction

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Keywords: perceived value, satisfaction, usage intention, electronic vehicle (EV), electromobility.
Abstract: Nowadays, electric vehicle innovation plays an important role in the market, transportation, logistics and supply chain in the electric mobility industry, contributing to environmental protection and reducing pollution. The commercial EV launched in Thailand which has been very popular with consumers, but it is also not widely used, and there are not many market surveys about customer usage intention. Therefore, it is necessary to study seriously. This study explores the impact of the perceived value of electric vehicle (EV) features on consumer usage intention to use electric vehicles in Thailand, with the mediating effect of customer satisfaction. The results showed that perceived value from using EV, consumer satisfaction, and usage intention of EV, there is a significant direct and indirect relationship. These findings have contributions and relevant expected benefits.

1 Introduction

The global automotive industry is growing rapidly and growing and undergoing a major transition. Especially, the quality of production and distribution of electric vehicles (EVs). Electric vehicles are an efficient alternative to maintaining urban transportation through reducing dependence on oil and air pollution. It leads to significant social values, health and environmental value.

Outlook for electromobility. That use energy consumption in electromobility systems is significant. To meet the expectations and needs of customers in the global market. It not only affects the consumer electric vehicle usage context but also the market and the value chain.

International Energy Agency (IEA) (2022) report states that "the world of clean energy is as dynamic as the electric car market". Sales of EV doubled in 2021 from the previous year to a new record of 6.6 million. Compare with 2012, just 120,000 EV were sold worldwide. EV markets are expanding quickly. Europe and China accounted for more than 85% of global electric car sales in 2021, followed by the United States (10%) [1]. In addition, accelerating global demand for electric vehicles has led to the development of the electric vehicle market ecosystem, including the manufacture of automobiles and critical parts such as electric motors, power generation, charging utilities, batteries, regulations and consumer demand [2]. Global electric vehicles are expected to grow rapidly, including in China, European countries, and the United States, which will eventually affect the automobile industry in Thailand inevitably. But despite this in comparison, consumer interest in electric vehicles in the country is still slower than the changes that have occurred abroad. Responding to global energy demand while facilitating the rapid increase in consumption in the domestic market.

From the aforementioned literature can clearly indicate that consumers are more satisfied with the benefits of using electric vehicles in the future. This study considered that the mediating effect of satisfaction on a perceived value on electric vehicle usage intention of customer the customer value is a very useful metric for EV businesses. It can tell us how much more customers spend on products or services. That customer will have more value for business. Because a business can't grow without these customers helping to buy products or services. It also includes and driven by demanding customers, delivering superior customer value, and keen competition has become a matter of concern in sustaining competitive advantage.

Alternative energy vehicles and EV innovations are something new for Thai consumer that have received significant attention. However, the number of EVs that are actually used on the road is still counted as a very small number. The survey and analysis of the role of consumer satisfaction as a mediating variable between the perceived values of electric vehicle consumption of domestic car users is therefore necessary to be seriously studied in order to suggest ideas readiness and needs of the population of car users in the country. In addition, the decision to adopt and use innovative technology that is new to EVs and has not yet been widely used in the country is still a delicate matter because consumers want consumption value and having to trade with a lot of risk and money. However, and the result is to increase and improve the efficiency of transport systems, logistics and supply chains in the EV industry. The next, we explore the mediating effect of satisfaction on a perceived value on electric vehicle usage intention of consumer in Thailand.

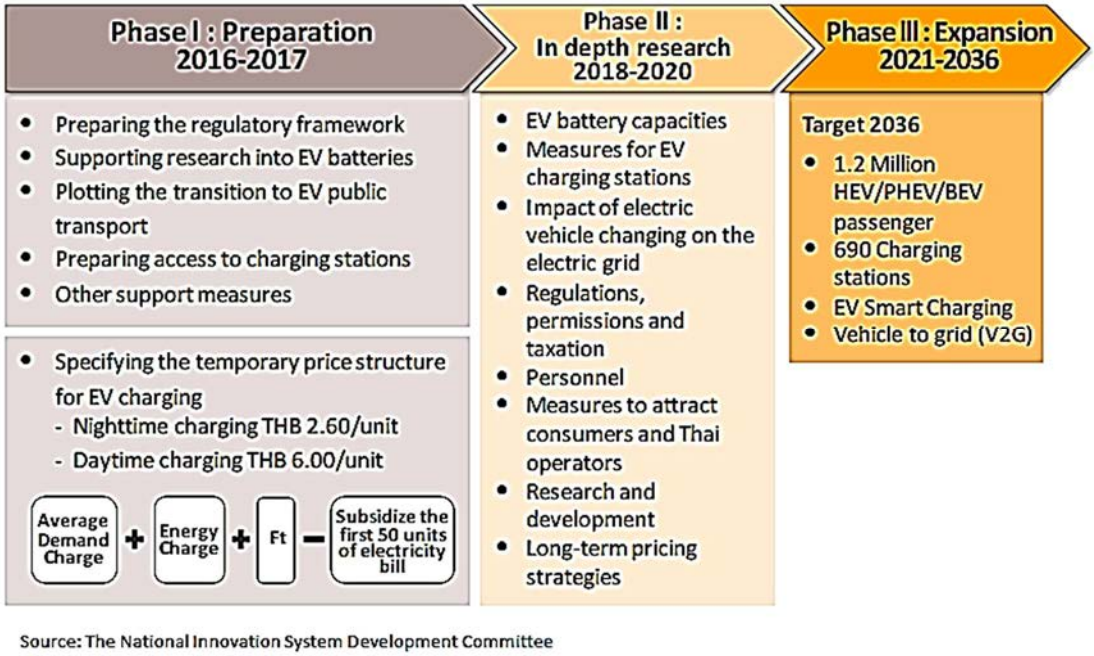

Figure 1 EV action plan (2016-2036) [3]

Year	ICE	% YoY	Electric Vehicles (EVs)						
			HEV & PHEV	% YoY	BEV	% YoY	Total EVs	% YoY	% share of EVs
2015	550,707	-12.8	7,629	-16.2	14	133.3	7,643	-16.1	1.39
2016	897,585	63.0	9,576	25.52	2	-85.7	9,578	25.3	1.67
2017	369,685	-58.8	5,966	-37.7	10	400	5,976	-37.6	1.62
2018	694,036	87.7	19,967	234.7	57	470	20,024	235.1	2.80
2019	739,213	6.5	26,424	32.3	650	1,040.4	27,074	35.2	3.66

Note: ICE: Internal Combustion Engine
Electric Vehicles Including HEV (Hybrid Electric Vehicle), PHEV (Plug in Hybrid Vehicle) and BEV (Battery Electric Vehicle)
Source: Department of Land Transport, compiled by Krungsri Research

Figure 2 Thai new registered passenger cars (units) [3]

2 Literature review

2.1 Previous studies on Electric Vehicle (EV) usage intention and theoretical background

Rogers's Theory of Diffusion of Innovation (DOI) (2010) describes how ideas or products/services are driven and diffuse through specific populations, economic, social, dynamic environments, innovations, and digital technologies. Affect the development of innovation over time. The concept of adopting new technologies also supports and indicates user behaviour towards the impact of its adoption and is most recognized for. In addition, TAM can also be linked to the perceived value of consumers in terms of perceived benefits and ease of use

of technology, and other factors can play a role through perceptions of the benefits and utilization of technology, perceived ease of use [4,5]. Finally, a theory that can be effectively used in conjunction with the above theory, for example, evolved from the theory of rational action (TRA) and planned behaviour theory (TPB) used to predict user intentions through function of attitudes, subjective norms and perceived behaviour control, and clearly explain the environmentally friendly behaviour, including the use of [6,7].

2.1.1 Electric Vehicles (EVS)

The Features of electric vehicles in terms of innovation, technology, image, and energy and environmental conservation properties affect perception and acceptance. It is also a matter of cutting-edge technology that meets the market and environment of car manufacturers, consumers, and people who focus on the conservation of the global environment today and contextual factors as shown in Table 1.

This study, we integrated the EV literature to determine the perception and acceptance of the features and market responses of EVs: (1) performance aspects such as marketing, quality standards, performance, usability, and get the benefits that are worthwhile, the devices and controls of electric vehicles are easy to use, suitable size, easy to find parking, the battery can be charged both at home and outside, stability of the car, distance travelled per full charge of the battery pot and responsiveness in driving, sturdiness, durability, design appearance, being recognized as a modern person, (2) It also has emotional, social and environmental relevance, pollution reduction, and service centers and after-sales services, security and sustainability systems., (3) the types of electric vehicles used in the study were electric vehicle type: battery electric vehicle (BEV), hybrid electric vehicle (HEV), plug-in hybrid electric vehicle. (PHEV), and fuel cell electric vehicle (FCEV)., and (4) Key features and market responses of Evs of consumer are integrated by implementing supply chain performance evaluation guidelines to provide legality, visibility, digitalization, integration and collaboration; and which leads to improvements in productivity efficiency and effectiveness; and which leads to enhancement of improvements in productivity efficiency and effectiveness for consumers and the electric vehicle industry [8,9]. However, behavioural intentions of using EVs of consumers still have both barriers and benefits waiting to develop the key features of electric cars to be efficient and effective for transportation and logistics in the future [10].

Table 1 Literature Review of Key features and market responses of EVs

Key features and market responses of EVs		Literature review
Technology and innovation	context	
Performance	Cost, fuel economy, environmental credentials, lifestyle image, social influence	Knapčíková [8], Oubrahim, et al. [9], Griskevicius, et al. [11], Almansour [12], Huk, et al. [13]
Performance attributes	Environmental concerns, financial benefits, government interventions, infrastructure readiness, social influence	Huk, et al. [13], Sang and Bekhet [14]
Quality and standard, epistemic value	Price, emotional value, environmental concern, reduction of emission	Knapčíková [8], Oubrahim, et al. [9], Han, et al. [15]
Acceleration, range, safety charging time, low noise	Price, perceived unit, incentives, infrastructure	Knapčíková [12], Higueras-Castillo, et al. [16]
Convenience, performance, produce less noise, cruise range, charging resources	Cost, environment-friendly, government policies, daily requirement, high-quality supplier services	Knapčíková [8],Oubrahim, et al. [9], Yan, et al. [17]
Battery life, convenience of charging station network	Concerning symbolism, fuel prices, social and financial, fuel consumption, price, environmental concerns	Huk, et al. [13] , Miranda and Delgado [18]
Performance and personal innovativeness	Price, environmental concern, facilitating condition, perceived enjoyment, social influence	Knapčíková [8], Oubrahim, et al. [9], Huk, et al. [13], Khazaei and Tareq [19]
Performance, technological consciousness, usefulness and ease of use	Social influence, marketing, perceived benefits, price, perceived barriers, policy attributes	Oubrahim, et al. [9], Hegner, et al. [20], Krishnan and Koshy [21]

2.2 Research model and hypotheses development

2.2.1 Perceived value

Perceived value as a strategic imperative for manufacturers and retailers in the 1990s, it will continue to be important into the 21st century [22]. Consumers decide whether to buy one type of product or service rather than one type. Otherwise, based on the perceived value of the product performance, characteristics, consequences and services that meet consumer [23]. Perceived values can be measured by one-dimensional or multidimensional structures [24]. A multidimensional structured knowledge that combines aspects (such as price, quality, benefit and sacrifice) to represent the concept of perceived value [22,25,26].

Customer satisfaction [27,28] are based on the role of customer perceived value as an antecedent of customer satisfaction. Some studies have examined service quality as an antecedent of satisfaction, which most of these models incorporate benefits [29]. The marketing executives try to estimate the value of their products in relation to their quality characteristics, such as functionality, performance, usefulness, technical characteristics, and the status proffered by owning them. In addition, focusing on service quality characteristics carries the important meaning of service, that is, the availability, support and dedication offered to the customer consumption value theory several value concepts can be measured and describe:

- Functional value perceived as a benefit derived from the expected perceived quality of a product or service. It is considered the main driver of consumer choice. This assumption supports the theory of economic utility [30,31]. For functional values of vehicle purchasing decisions can be derived from features such as reliability, durability, price, fuel economy, and maintenance. These values are contribute and independent to consumer choices in a given situation, such as functional values, conditional value or convenience value and monetary value which meet the needs and uses for physical purposes [16,26,32]. Performance value/ convenience value means a facilitation condition is defined as an individual insight into the infrastructure or technical support available for the use of a modern technological system. In terms of EVs, it is considered convenient in the ease of use of the various equipment and controls of an electric vehicle, versatility battery charging, after sales service and service centers are of high quality, and monetary value. Customers are intent on buying electric vehicles, even if they are expensive, and the government will try to reduce the price difference by using incentives. The EVs are still expensive but customers are willing and willing to buy electric cars. In spite of government support policies, trying to reduce the price difference by using incentives, tax measures in the context of environmentally friendly products. Many scholars have found that price value is one of the biggest barriers to friendly products. However, with marketing strategies and personalization, innovative people may reduce barriers [20,33,34].
- Non-functional values such as emotional value, the product's ability to stimulate the consumer's mood, the benefit derived from the emotional state that a product or service generates. It could be a positive or a negative emotion [16,35]. Goods and services, often associated with emotional responses. Emotional values are often associated with aesthetic choices, however, products that are more tangible and seem more useful also have emotional value. [25]. Marketing and promotional variables also drive emotional responses that may be typical for the product being marketed [26,36]. The language of the manuscript is clear and understandable.

As for social value, the social benefit derived from a product or service, about the utility of the product to demonstrate social acceptance, and enhance consumer image [16,35]. Social values are also linked to social, economic and cultural stereotypes in a positive or negative way. This, as measured by alternative image profiles [26], is consistent with consumer societal norms to show others how they are when making purchases for goods and services [22]. Epistemic is the ability of products and services to arouse curiosity or desire for new experiences. Product capabilities within a specific context in situations where consumers have to [26,32,37].

Furthermore, multiple values, namely the consumption values that influence consumer choice behaviour, such as work, social values, emotional values, epistemological values, and conditional values. The decision can be influenced by the consumption values. This fulfils a high level of consumer need [26,38]. Values derived from TAM amplification [4,5], and environmental values. This is due to energy and environmental conservation and technological innovations that enhance the satisfaction of consumption of goods and services resulting in sustainable customer behaviour [9,13,39,40].

However, the concept of perceived value often differs slightly from other related structures such as value, utility, price, and quality. Its use and its worth in terms of gain can be indicated in the form of integration that can be referred to about NFV and FV such as technology, convenience, ease of use, cost savings, risks and safety. These can be explained by the TRA, TPB, TAM, the generation of people, personal beliefs and preferences, and the relationship behaviours related to readiness for adoption of new technologies.

In addition, the value gained also includes the benefit of the functionality that is more cost-effective from the use of various technologies in assistive devices compared to

the time spent, the efficiency of features on the device used is stable, accessible content and services, the device is efficient in navigating relevant information with ease, and Eco-friendly, technological performance, driving enjoyment benefit, worthiness for prices and cost [39,41].

We concluded that the perceived values of other relevant research studies were classified into the same functional value and non-functional values, as shown in Table 2.

Table 2 Literature review of Perceived value

Functional Value			Non-functional Values			Literature review
PEV	COV	MOV	ENV	SOV	EMV	
✓	✓	✓	✓	✓	✓	Hur, et al. [42]
✓	✓	✓	-	✓	✓	Watjatrakul [37], Chen and Lin [43]
✓	✓	✓	-	-	-	Ranaweera and Karjaluoto [44]
✓	✓	✓	✓	✓	✓	Jansri [45]
✓	✓	✓	✓	✓	✓	Kim, et al. [41]
✓	✓	✓	✓	✓	✓	Han, et al. [15], Hegner, et al. [20]
✓	-	✓	✓	✓	✓	Amin and Tarun [46]
-	✓	✓	-	-	-	Bashir, et al. [47]
✓	✓	✓	✓	✓	✓	Rasoolimanesh, et al. [48]
✓	✓	✓	✓	✓	✓	Miranda and Delgado [18]
-	-	-	-	✓	✓	Giantari, et al. [49]
✓	✓	✓	-	✓	✓	Liu, et al. [50]
✓	✓	-	-	-	✓	Uzir, et al. [51]
✓	✓	✓	✓	✓	✓	Salari [52]

Note: PEV=Performance Value; COV= Convenience Value; MOV= Monetary Value; ENV=Environmental Value; SOV= Social; Value; EMV= Emotional Value

2.2.2 Perceived value

Customer satisfaction is established concept in several areas like marketing and consumer research, psychology, and economics [53]. Satisfaction feeling is an attitude. Mixed feelings, as a consumer may have different levels of satisfaction for different parts of product or service experience [54-58]. Outcomes of satisfaction feelings may involve intent to complaints and repurchase [57]. These outcomes also are moderated by other variables. For example, extreme dissatisfaction will not necessarily generate complaint behaviour, if the consumer believes complaining will be futile [53]. In addition, trust in products/services also indicates the level of customer satisfaction with significant benefits, such as social value, emotional value, and taking advantage of functional value [46,55-57].

The value concept as a catalyst in product choice and satisfaction's relationship to it as a brief psychological reaction to a constituent of a value chain. A significant point about customer value models is the use of gross benefit with cost judgments by consumers. The association of overall service satisfaction, encounter satisfaction, and perceived service quality takes a form of perceived quality as a separate structure and differs from satisfaction [51-53,57].

One form of intent is the degree to which consumers separate their purchases between alternatives. As with many brand loyalty, consumers may intend to show a set of acceptable alternatives. However, it is known that stated intentions without behavioural checks are highly unreliable. Consumers often exaggerate their intentions because they have a positive bias in their responses rather than using other measure of satisfaction. Intent data may be one of the best measurement methods [52,53]. Adding more unique features will increase the perceived value of the service and increase customer satisfaction [12,21]. As shown in table 3. And we make the following hypothesis:

- H1: Functional value has a direct effect on satisfaction.
- H2: Non-functional value has a direct effect on satisfaction.

Table 3 Literature review of satisfaction and usage intention

Variable	Literature review
Satisfaction	Khazaei and Tareq [19], Hur, et al. [42], Bashir, et al. [47], Giantari, et al. [49], Bernarto and Purwanto [59], Ashraf and Niazi [60], Hapsari, et al. [61], Rouibah, et al. [62], Sadia [63], Su, et al. [64]
Usage Intention	Han, et al. [15], Khazaei and Tareq [19], , Krishnan and Koshy [21], Asadi, et al. [39], Hur, et al. [42], Adnan, et al. [65], Alzahrani, et al. [66], Huang and Ge [67], Magotra, et al. [68], Tu and Yang [69], Vafaei-Zadeh, et al. [70]

2.2.3 Satisfaction

Consumer satisfaction in the form of expectations and confirmation of expectations [57,58], on the other hand, is believed to influence changes in attitudes and purchase intent. The outcomes of satisfaction decisions were attitudes and intentions that were modified accordingly. well reflected by the results. Satisfaction experiences influence future purchase intentions. well as later purchase attitudes, most consumer behaviorists will agree that buying dissatisfied products should reduce the inclination to purchase [56,58]. This means that the intended use will be reduced accordingly. The satisfaction and dissatisfaction characteristics were significantly correlated with positive and negative effects, respectively. and to overall satisfaction It is recommended that all dimensions be tested for complete accounting of the post-purchase response in use [27,28,58]. And we make the following hypothesis:

- H3: Satisfaction has a direct effect on usage intention.

2.2.4 Usage Intention

The TRA, TPB, TAM were supposed to have considerable capabilities as a tool to enhance the prediction of consumers' Intention concerning environmentally friendly behaviours, including the adoption of EVs [21]. As shown in Table 4.

2.2.5 The Mediating effect of satisfaction on perceived value and usage intention

The customer value affects customer satisfaction, customer satisfaction affects customer loyalty [27,28]. Customer value is also positively related to usage intention. Theoretical justification for the mediating role can be attributed to a well-investigated framework in attitudinal literature [6,7]. Attitudes, preferences, and partitioned attitudinal antecedents, cognitive, emotional, driven, persistent intentions in innovation and technology [54,63]. Customer value indicates customers' rational trade-off between the benefits-costs of using a product/service and thus is regarded as a cognition variable. Customer satisfaction is an affect variable. Customer usage purpose concerns behaviour or a disposition to perform positively toward a product/service provider. In addition, trust in products/services also indicates the level of customer satisfaction with significant benefits, such as social value, emotional value, and taking advantage of functional value [46,54,57] and lead to increased customer loyalty [56,58,69,70]. In addition, there are studies that support the mediating of customer satisfaction to usage electric vehicles, as shown in table 4 and figure 3. Thus, the framework provides a basis for hypothesizing that satisfaction mediates the effect of functional value and non-functional value (perceived value) on usage intention. However, marketing and consumer study also suggests that perception about a product may affect purchase behaviour directly for some product categories. And we make the following hypothesis:

- H4: The mediating effect of satisfaction on functional value and usage intention.
- H5: The mediating effect of satisfaction on nonfunctional value and usage intention.

Table 4 Literature Review of The Mediating effect of satisfaction

Pperceived value	Satisfaction		Usage intention	Literature review
	Direct effect	Mediating effect		
Functional value	-	✓	✓	Abu Elsamen [71]
	✓	✓	✓	Nugroho, et al. [72]
	✓	✓	✓	Giantari, et al. [49]
	✓	✓	✓	Amin and Tarun [46]
Non-functional value	✓	✓	✓	Rasoolimanesh, et al. [48]
	✓	✓	✓	Giantari, et al. [49]
	✓	✓	✓	Amin and Tarun [46]

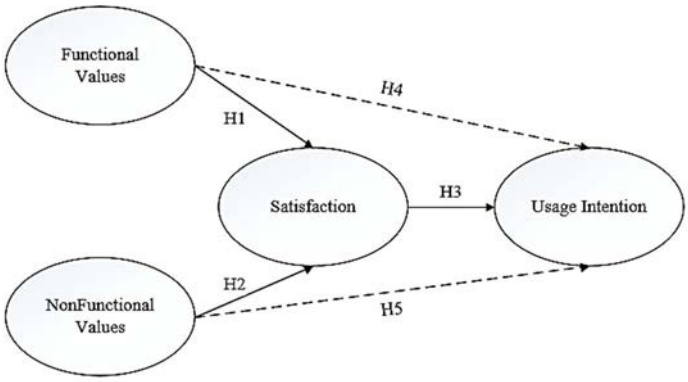

Figure 3 Research model

3 Methodology

As an empirical research, we focus on using questionnaires as a data collection tool, focusing on customers who have already used EVs. Statistical analysis uses structural equation modeling techniques to answer research objectives and research hypotheses.

3.1 Design of the questionnaire

The data collection instrument consisted of questionnaires, consisting of quantitative attitude and demographic data questionnaires, which measure 4 latent and manifest variables functional values, non-functional values, usage intention and satisfaction. The Likert scale of the 6-point scale was scored an evaluation questionnaire on the acceptance of the value obtained from the use of EV as 1= extremely unacceptable, and 6= extremely acceptable. In addition, the test results for the validity of each variable had an alpha Cronbach coefficient of .866-.928, appropriate for cognitive tests such as intelligence tests.

3.2 Data collection

Data collection was carried out using a questionnaire. The questionnaires data analysed were used to determine the size of the sample. By specifying the ratio of 10 samples to 1 variable, this equalled 18 member of observed variables= 18 x 10 = 180 cases, and used convenience sampling. Data collection period from Sep to Dec 2021 for a total of 45 days.

4 Data analysis

4.1 Descriptive statistics

Descriptive statistics on demographic profile. Among all the respondents, only 56.08 percent are male, average of ages are 36, there are 40 respondents (27.03%) in Gen X and 104 respondents (70.27%) in Gen Y, Incomes 25,000 baht/ month, Completed a bachelor's degree 58.78 %, 1-6 months of experience in using a EV 45.27%, and the first EV in the family 75.68 %. In addition, the service quality of electric vehicle service centers (10 points) was assessed in (1) overall service quality was good with an average score of 8.22, and (2) overall service quality of the problem claim was good with an average score of 8.17, as can be seen in figure 4-5.

4.2 Structural equation model analysis results

Because of this study, a small sample size was obtained. The analysis of the Structural Equation Model (SEM) required a simple model with small samples should be held to strict fit standards [73]. We take precautions in view of the small sample size used for structural equation model analysis. The test of consistency between the goodness of fit measures in the model was found to be in harmony with the fit of the model, with result: Chi-square ($\chi 2$) = 129.613, df = 108, CMIN/DF ($\chi 2$/df) = 1.200, GFI = .916, CFI = .991, NF = .948, TLII = .987, and RMSEA = .024 (Figure 6). It could be concluded that the form of the structural equation of the variables effecting customer usage intention was consistent with the empirical data [56,74,75]. Accordingly, the statistics Goodness of fit as shown in Table 5.

Figure 4 service quality of electric vehicle service centers

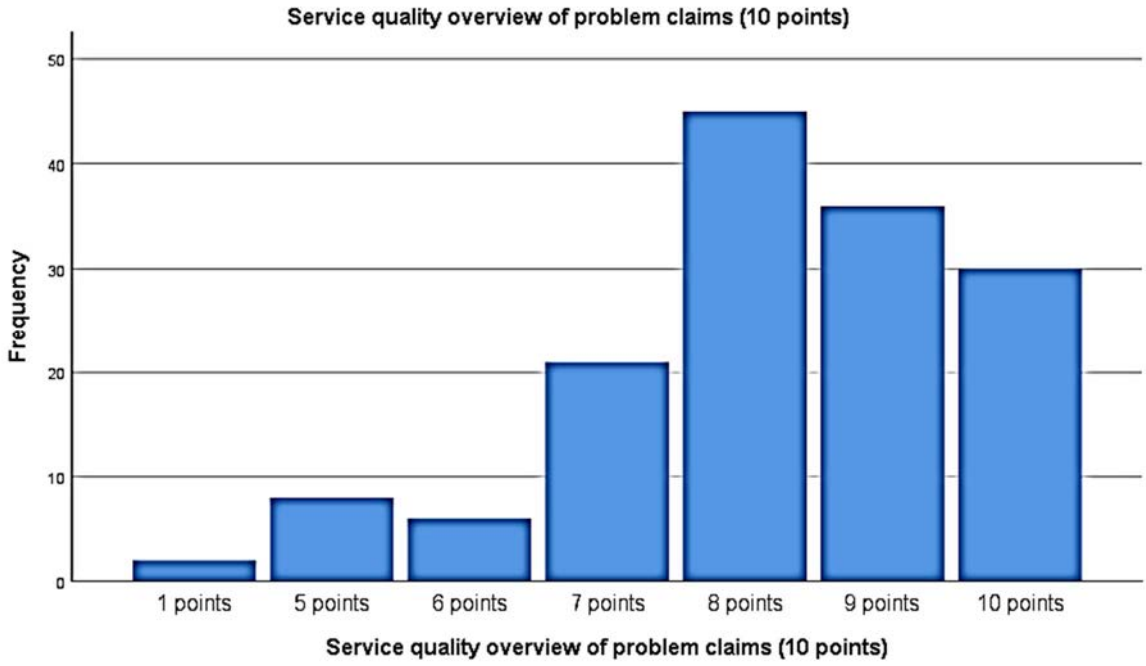

Figure 5 overall service quality of the problem claim

Table 5 Statistics Goodness of fit

Relevant Statistics	Criteria	Test Value
Relative Chi-square	$\chi 2/df < 2.00$	1.200
Goodness of Fit Index	GFI >.95	.916
Comparative Fit Index	CFI >.95	.991
Normed Fit Index	NFI>.95	.948
Tucker-Lewis Index	TLII >.95	.987
Root Mean Square Error of Approximation	RMSEA <.05	.024

4.3 Results of testing of the hypotheses

Hypothesis testing shall provide the same as the Structural Equation Modelling by considering the C.R. (t-value) and p-value used for the test of the hypothesis. The hypothesis analysis was executed using the IBM SPSS AMOS software. It indicates that values higher than 1.96 for all hypotheses of statistical significance. It can be concluded that the results support all assumptions and that the results of they are shown in table 5 and 6, and the final model Figure 6.

Hypothesis 1: Functional value has a direct effect on satisfaction. The hypothesis testing is concerned with standardized effect =.813, that supports a statistically significant hypothesis at p<0.05.

Hypothesis 2: Non-functional value has a direct effect on satisfaction. The hypothesis testing is concerned with standardized effect =.578, that supports a statistically significant hypothesis at p<0.001.

Hypothesis 3: Satisfaction has a direct effect on usage intention. The hypothesis is concerned with standardized effect =.886, that supports a statistically significant hypothesis at p<0.001.

Hypothesis 4: The mediating effect of satisfaction on functional value and usage intention. The hypothesis testing is concerned with standardized effect =.309, that supports a statistically significant hypothesis at p<0.01.

Hypothesis 5: The mediating effect of satisfaction on non-functional value and usage intention. The hypothesis is concerned with standardized effect =.512, that supports a statistically significant hypothesis at p<0.001.

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

$$Satisfaction = .349\ Function\ Value + .578\ Non\ Function\ Value, R^2 = .821 \quad (1)$$

$$Usage\ Intention = .886\ Satisfaction, R^2 = .600 \quad (2)$$

Figure 6 Final model

Table 6 Analysis on the relationship of the variables

Relationship of Variables			Standardized Regression Weights	S.E.	C.R.	*p*-value	Squared Multiple Correlations
Satisfaction	<---	Functional Values	.349	.156	2.484	*p*<.05	.821
Satisfaction	<---	Non Functional Values	.578	.142	3.946	*p*<.001	
Usage Intention	<---	Satisfaction	.886	.118	7.569	*p*<.001	.600
MOV	<---	Functional Values	.809	-[a]	-[a]	-[a]	.655
COV	<---	Functional Values	.914	.079	13.579	*p*<.001	.835
PEV	<---	Functional Values	.875	.086	12.746	*p*<.001	.766
EMV	<---	Non Functional Values	.883	-[a]	-[a]	-[a]	.780
SOV	<---	Non Functional Values	.887	.066	15.149	*p*<.001	.787
ENV	<---	Non Functional Values	.870	.078	11.990	*p*<.001	.756
SAT1	<---	Satisfaction	.755	-[a]	-[a]	-[a]	.571
SAT2	<---	Satisfaction	.837	.113	10.561	*p*<.001	.701
SAT3	<---	Satisfaction	.781	.115	8.979	*p*<.001	.610
SAT4	<---	Satisfaction	.786	-[a]	-[a]	-[a]	.618

Relationship of Variables			Standardized Regression Weights	S.E.	C.R.	*p*-value	Squared Multiple Correlations
Satisfaction	<---	Functional Values	.349	.156	2.484	*p*<.05	.821
Satisfaction	<---	Non Functional Values	.578	.142	3.946	*p*<.001	
Usage Intention	<---	Satisfaction	.886	.118	7.569	*p*<.001	.600
MOV	<---	Functional Values	.809	-[a]	-[a]	-[a]	.655
SAT5	<---	Satisfaction	.796	.087	11.055	*p*<.001	.634
SAT6	<---	Satisfaction	.833	.124	10.707	*p*<.001	.694
UI1	<---	Usage Intention	.718	-[a]	-[a]	-[a]	.515
UI2	<---	Usage Intention	.732	.087	11.055	*p*<.001	.536
UI3	<---	Usage Intention	.907	.124	10.707	*p*<.001	.823
UI4	<---	Usage Intention	.832	.101	11.536	*p*<.001	.693
UI5	<---	Usage Intention	.747	.101	10.044	*p*<.001	.558
UI6	<---	Usage Intention	.860	.125	10.276	*p*<.001	.740

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

Table 7 Hypothesis test results

Hypothesis	coef.	Results
H1: Satisfaction <-- Functional Value	.349*	Supported
H2: Satisfaction <-- Nonfunctional Value	.578***	Supported
H3: Usage Intention <-- Satisfaction	.886***	Supported
H4: Usage Intention <-- Satisfaction <-- Functional Value	.309*	Supported
H5: Usage Intention <-- Satisfaction <-- Non-functional Value	.512***	Supported

Note: * = *p*<.05; : ** = *p*<.01; *** = *p*<.001

Table 8 Standardized direct, indirect, and total effects of the factors test results

Effects	Total			direct			Indirect		
Variables	FV	NFV	SAT	FV	NFV	SAT	FV	NFV	SAT
SAT	.349	.578	-	.349	.578	-	-	-	-
UI	.309	.512	.886	-	-	.886	.309	.512	-

Note: Functional Value (FV), Nonfunctional Value (NFV), Satisfaction (SAT), Usage Intention (UI), - as .000

5 Discussion and implementation

5.1 Management implications

The findings of this study may assist the marketing business and organizations of the automotive industry with the understanding of consumer behaviour in using electric vehicles, and develop business strategies designed to meet consumer needs issues. Marketers should attach importance to products and service non-functional benefits as well as social value, environmental value and emotional value. Marketers should prioritize the mediating effect of satisfaction, because it can lead to a loyal customer base in the future. This phenomenon can be explained by the theory of planned behaviour (TPB), technology acceptance model (TAM), and theory of reasoned action (TRA) on predicting customers' usage intention, and concluded that three theories could explain intention quite well, and TAM is better when measuring the general satisfaction level. In addition, the results suggest that emotional value is the most important value for the selection of EVs by consumers. It can be used as triggers to improve the potential and assist them form more positive satisfaction towards usage intention EVs.

5.2 Research implications

This research is a cross-sectional study. Therefore, first longitudinal studies should be conducted so that changes can be more accurate and their application in studies to look for other predictors, second precaution is concerned with the small sample size used for multivariate statistics analysis, and finally the sample size should be collected in consistency with the parameters in the research model [73].

6 Conclusions

The analysis also showed that the functional value and non-functional value as demonstrated performance value (PEV), convenience value (COV), monetary value (MOV), environmental value (ENV), social value (SOV), and emotional value (EMV) may have less influence in fulfilling customers need, satisfaction, and the intention to use electric vehicles significantly. In addition, the analysis

also showed that the non-functional value of electric vehicle users was more influential than the functional value, indicating that the social value intent (SOV) was first followed by the Thai customer, followed by environmental value (ENV) and emotional value (EMV), respectively. It may relevant to the perceived utility that consumers derive from their association with specific groups in society. Personal norms can explain the perceived social pressures of Thai customers that influence product adoption and decision-making processes. This may affect the customer's decision-making process [20,13,27,58].

Studies have shown the limitations of different approaches to the complexity and multidimensional nature of perceived values. The decision to buy and use EVs [16,65], has to go through credibility to increase the level of consumer satisfaction that has been used goods and services [29,31,46,57,58,63,74].

The results of this study may help organizations and marketing businesses of the automotive industry understand Thai consumers' behaviour in using electric vehicles. And develop innovative business strategies designed to meet the needs of consumers in early adopters and expansion markets [29,75-77]. And enhance in direction and continuous improvements in market response and consumer EV attributes are consolidated through the use of automotive supply chain performance [8,9,13].

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Streamlining utilisation of the assembly line using computer simulation
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Streamlining utilisation of the assembly line using computer simulation

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Keywords: modelling, simulation, manual assembly, advanced industrial engineering.
Abstract: The increase in computer computing power and the development of simulation software make it possible to realise very accurate predictions of the impact of decisions on systems. The cost of investments in streamlining logistics and manufacturing systems is usually high. Therefore, verifying whether the implemented improvement will have a real intended impact on the system is necessary. The use of simulation helps reduce the risk of uncertainty in such projects. The article describes the simulation performed in the software Tecnomatix Plant Simulation 15.2 and their use in its described methodology for simulation study with achieved results. The study was carried out to streamline manual assembly in a company engaged in the production of car seats, namely car rear seats and their manipulation processes. The simulation itself was supposed to answer the question of whether it is possible to produce faster customer line tact and whether it is possible to reduce the number of workers without influencing line performance. The very design of the content and number of simulation experiments was realised in two main aspects. These aspects are whether changing the organisation of the workplace will bring the desired effect and whether the installation of new equipment can improve performance even more. The resulting solution helped reduce the investment uncertainty and estimated that the best two solutions would increase the assembly line performance by 0.94% or 6.89%, respectively.

1 Introduction

Manufacturing companies are now increasingly facing problems of rapid implementation of change to their processes. Often these changes are introduced without careful consideration of all benefits and negatives. These negatives can outweigh all the benefits, and businesses will only find out after all the changes and innovations have been introduced. Therefore, during production, they have to deal with problems for which they were not sufficiently prepared. Ultimately, this can lead to higher workplace failure and, thus, a decrease in performance. However, the need for these changes is increasing to improve performance and quality.

Potential problems can be avoided by using various tools to predict the future state of the devices and the advantages and disadvantages of the individual solutions proposed. Current trends in the support tools of production systems designed to solve the problem of rapid seduction of change are directed to digitisation, making it possible to solve decision-making tasks in the digital environment. Now the trends of Industry 4.0 have become emergent in companies. Industry 4.0 technologies include simulation [1]. The production system, as we know, has three components (inputs, transformation process and outputs). In other words, just as we set up an efficient transformation process, such results we will be able to expect. Many companies have been successful for a long time precisely because they are volatilely trying to optimise and streamline their internal processes [2,3]. This brings added value to companies, especially in reduced costs or increased production. Various techniques from LEAN through Sig Sigma are used in optimising production and assembly systems. However, only some of the methods allow a glimpse into the future as accurately as a computer simulation [4,5].

Computer simulation imitates system behaviour and internal processes over time and appropriately concludes system behaviour. Simulation models are compiled using the simulation software. [6]. The simulation is used to predict the effect of changes on existing systems and the performance of new systems. Computer simulation allows verification of decisions and their variation to achieve maximum synergy effect without interference with the real system [7]. It is most often used in processes where we design new systems and do not know their specific behaviour, so their applicability ranges from mechanical processes [8-10] to production processes [11]. This allows us, for example, to accelerate the start-up of new products,

verify future investments, verify our scheduling plans, check the current state of planning, optimise and streamline the current system. Using simulation is possible to find many statistics that help detect bottlenecks, even in places where they are seen in normal view. The advantages of using simulation lie in its benefits. The simulation can provide information on the proposed solutions already during the decision-making process. On this basis, the optimal solution can be chosen.

The saving of time and mainly costs that the simulation provides is a great asset due to the increasing pressure on the necessity of change. It is a very effective tool, especially in assembly processes, where it can detect and remove bottlenecks, thus improving the overall quality, whether product or production plan. The assembly process is a process that is particularly sensitive to the timely follow-up of processes. In other words, the performance of our system will be just as high as it is in its bottleneck place. This is especially true in processes where it is impossible to create buffers that compensate for time disproportionates. The height of the output from the assembly system depends on good line balancing and the correct distribution of logistics activities. Computer simulation allows testing the layout of activities so that times for individual workplaces are as close as possible.

As it turned out in practice, the application of simulation has problems. Most often, problems associated with communication between the designer and the simulation specialist are pointed out. The basis of such issues can be a need for more knowledge about the possibilities of applying simulation on the part of the designers or their excessively high requirements for simulation [12]. Here, too, it is necessary to realise that a simulation is only a support tool for decision-making, it cannot replace the designer's creativity, and in the end, the designer must make the fundamental decisions and take full responsibility for them [13]. These problems gradually disappear after the participation of designers in the solution of several simulation studies. Designers better understand the possibilities of simulation, penetrate into the depth of problems, gradually become familiar with the simulation system and, over time, can solve simple tasks independently. Such a procedure is usually the most advantageous for project departments in companies.

At its core, the article describes the use of computer simulation for streamlining manual assembly respectively for determining the results of individual decisions on a solved system. The simulation model creation was carried out in cooperation between the simulation specialist and the responsible workers on the line, and the simulation was realised in cooperation between the specialist and the designer. Tecnomatix Plant Simulation 15.2 software is used for simulation, allowing dynamic system simulation.

2 Materials and methods

Modelling and simulation find their application in dealing with many tasks for which a routine estimate is no longer sufficient. It has been applied to a wide variety of settings. The following are just a few samples of areas where simulation has been used to understand and improve the system's effectiveness: airports, hospitals, ports, mining, amusement parks, call centres, supply chains, manufacturing, military, telecommunications, the criminal justice system, emergency response system, public sector, and customer service [7]. The simulation finds its dominant application mainly in industry, where vast volumes of money must be invested to establish production capacities. Therefore, the result we want to achieve must be verified in advance to achieve maximum effect. The production area covers both the area of manufacturing and logistics. Several works were involved in the application of simulation in production. The simulation of the production facilities and production flows was dealt with by [14-17]. The simulation of logistics processes carried out through supply tractors was dealt with by [18] testing different layouts of multi-company multimodal logistics systems [19] by analysing simulation techniques in logistics [20], optimising logistics warehouses [21] and [22], simulating logistical flow using the kanban system [23]. By simulating workers using genetic algorithms solved [24], worker allocation planning of a medical device distribution centre [25], and evaluation of the effect of worker turnover on productivity [21]. The simulation of reconfigurable production systems was solved by [20] simulation of progressive production concepts through metamodels in [26]. From the width of the current use of simulation in databases, it can be assessed that the application of simulation in production will only grow. The article itself is an extension of existing knowledge and its use, especially in manual assembly.

2.1 Chosen simulation study methodology and simulation tool

The actual implementation has been realised according to the general methodology of conducting a simulation study for the manual assembly workplace and its steps defined in Figure 1.

The simulation project begins with an analysis of the real system, a definition of the problem, and clarifying the simulation's aim. For the needs of the computer model, it is necessary to collect and process as much information as possible about the means of production or knowledge of the workers themselves from the solved assembly line since it is a manual assembly. After this step, an abstract logical model is then created, and the model created on a computer is validated. The next step is to create the model itself and verify the correctness of the model concerning the formulated parameters – verification and pilot runs. After that, simulation experiments are planned and prepared. We carry out experiments by changing parameters or modifying the model. Given results from the experiments carried out are evaluated and processed. If the results of the experiments are satisfactory, changes to the real system shall be applied.

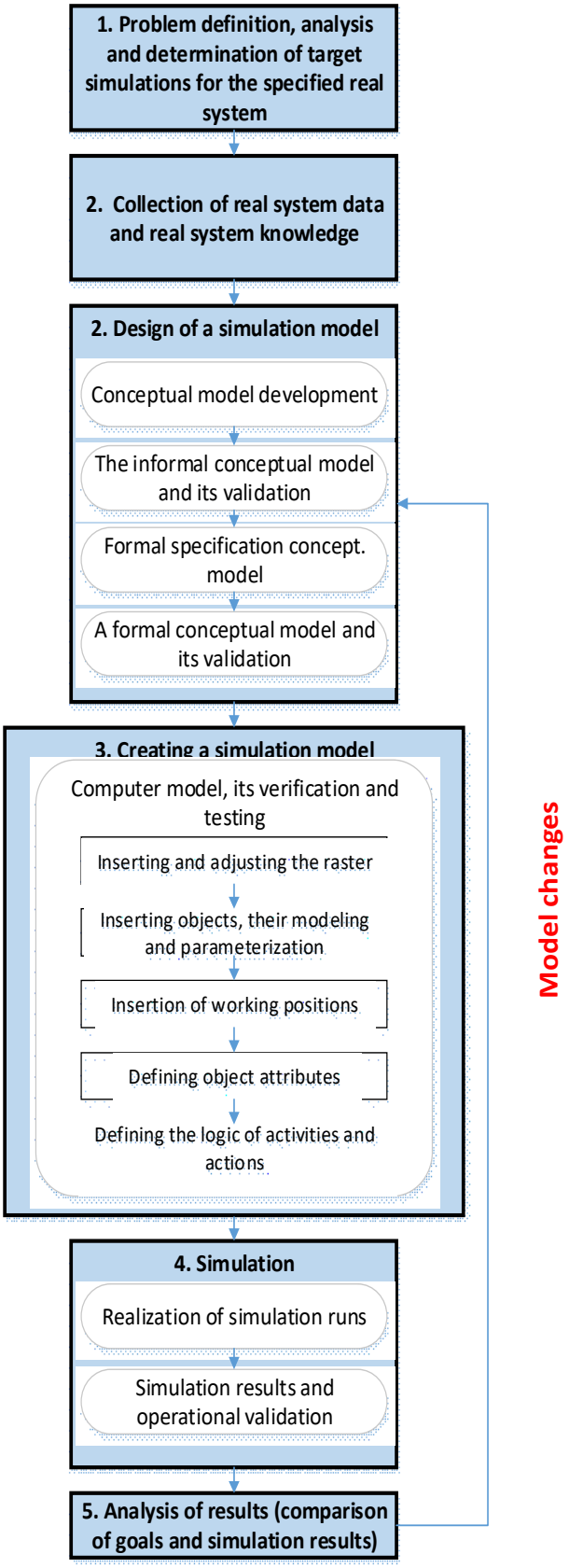

Figure 1 General procedure for carrying out a simulation study for a manual assembly workplace

In case of inconsistencies in comparing the objectives and results of the simulation, a model change shall be made. Tecnomatix Plant Simulation 15.2 has been selected as a simulation tool. This is software allowing dynamic simulation of the system. The functions of Tecnomatix Plant Simulation enable the creation of a digital model of real logistic systems (for example, production flow, material flow in supplying, etc.), thanks to which experiments and control of individual courses and system characteristics can be done.

2.2 Description of the simulated process

In the previous chapter, the methodology described was used to conduct a simulation study on the assembly line on which the rear seats of a passenger car are manually assembled. The display of the final product and input materials can be found in Figure 2.

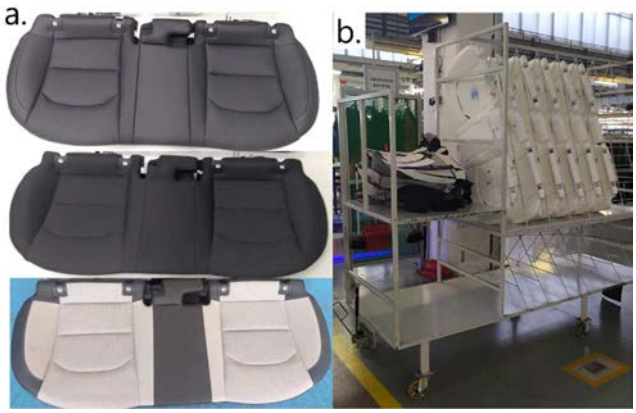

Figure 2 Illustration (a) of the final product; (b) of the input materials

It is a process where heating, pressure sensor, cables, cover, and isofix are gradually installed in the installation process. The initial hypothesis is that there is a distribution of activities and fewer workers where the output of the workplace is comparable to the current one. The layout of the selected material flow assembly process itself is in Figure 3. The selected assembly process and the activities carried out in it do not have specified times for the operation but are determined by the customer's line tact. Therefore, there is a situation where the tact may be higher or lower in the workplace. A workflow is defined for each workplace to ensure the required quality of the product. The static position of material and workplace buffers is also defined. In the workplace, various variants of seats are assembled. These differ in foam, cover (vinyl-semi leather, leather, textiles), and heating.

The assembly procedure is the same for all types of products, except the case of heating installation. For this case, time is different due to the installation of this component. The supply of material to the assembly process is considered 100% as the downtime is negligible. As such, the assembly process follows the processes of preparing the input material and workplaces, where the installation of the

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upper part of the seat is carried out and at the workplace E04_2, are paired. Therefore, these processes interact, and when it is unsynchronous, one process affects the other by delaying. Both processes then affect loading the finished paired parts into the technological pallet for automatic put-away. When creating a simulation model on which simulation experiments are to be carried out, results can also be expected as the inputs are precisely defined. The definition and interpretation of the collected data have an important role, the correctness of which is confirmed at the verification and validation stage.

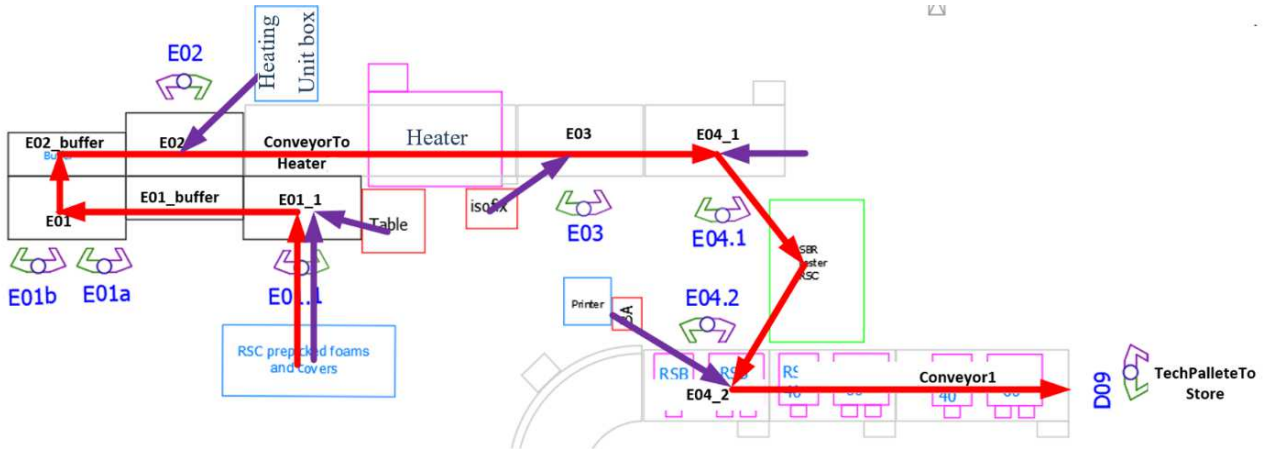

Figure 3 The layout of the manual assembly workplace and material flow

The data collection is based on the objective of the simulation project itself, based on which abstraction and reduction steps were carried out. As already mentioned, variations of the product differ in the foam used (PHEV, HEVSB, HEV, SB, 5DR, CUV), cover (vinyl-semi leather, leather, textiles), and heating (contains, does not contain). The material flow of the product is shown in Figure 3. The main flow of products is shown in red. The places of installation of the material are colour purple. The duration of activities in the workplace needs to be precisely determined. Their duration had to be measured directly in production. Based on data and the reduction of elements, a time has been set for three types of covers. Foams, even if they are different, do not change the duration of time for activity. A triangular distribution is selected for the data since, in production, it is possible to measure the minimum, maximum and medium duration of the activity, and the activities performed by humans are reflected in the time variation. For the possibility of future balancing of such times, the operation of the installation itself is divided into several activities. The activities come from workflows and are in the order in which they are carried out. The description of the process is as follows; take the foam, stick the pressure sensor, if it requires a heating application, then cover with a cover, shoot the cover on the seat, stretch the cover and attach it to the bottom of the seat, plugging in the heating unit and cabling, straightening, heating, installing the isofix, ironing and checking, assigning a label to control quality by the pressure sensor, final inspection and loading.

3 Results

The created simulation model consists of a line model in which the entire process of assembling the product takes place. Creation of a simulation model consisting of steps defined in the general methodology for conducting a simulation study in an environment of manual assembly. First, a raster was inserted from the CAD file, based on which the objects were modelled to actual dimensions. This is due to the correct distances for walking workers and the right restrictive conditions. After inserting and modelling objects, parameters have been defined for objects, workers, and products with assigned logical critical rules. In the end, the model is verified and validated once more. It is validated using order sheets. In one order sheet is printed time when the order of 8 seats enters the real assembly system. When the following order of 8 seats enters, the time is also recorded to determine how much time consumption this order takes. This was done for one hundred orders. The resulting difference with the real system was +/- 0.38%. The simulation model created in 2D and 3D graphics is in Figure 4. For the design of experiments, it is necessary to consider the company's questions, whether it is possible to produce faster customer line tact and whether it is possible to reduce the number of workers without influencing the line performance. Furthermore, it is necessary to analyse the results from the simulation model, which is validated with the real one. Essential indicators include the worker's utilisation graph Figure 5 and the workplace utilisation graph Figure 6.

In the production line, it is possible to identify two bottlenecks, namely the places with the highest tact times, E01 and E04_2. Looking at the workplace workload graph, Figure 6, it can be identified that the E04_2 creates a

MeasuringStation blocking and secondary blocking of E04_1. Also, the E02 and E03 workplaces are blocked due to E04_2 influence. The E01 workplace causes the blocking of the E01_1. The current output is 30.74 pieces per hour. The experiments were conducted based on analysis and are a combination of the number of employees, the deployment of work activities, their necessity and the ability to meet the requirements for customer line tact. At first, a series of merging experiments were carried out to determine the possibility of merging workplaces.

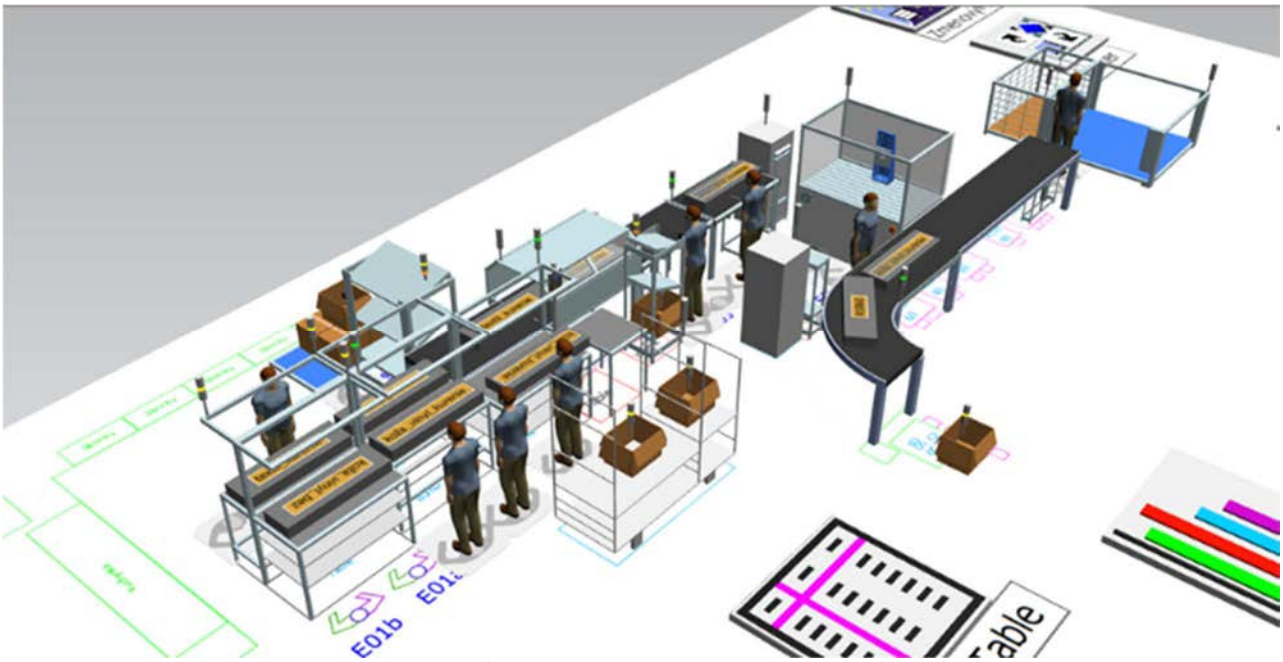

Figure 4 The layout of the manual assembly workplace and material flow 3D

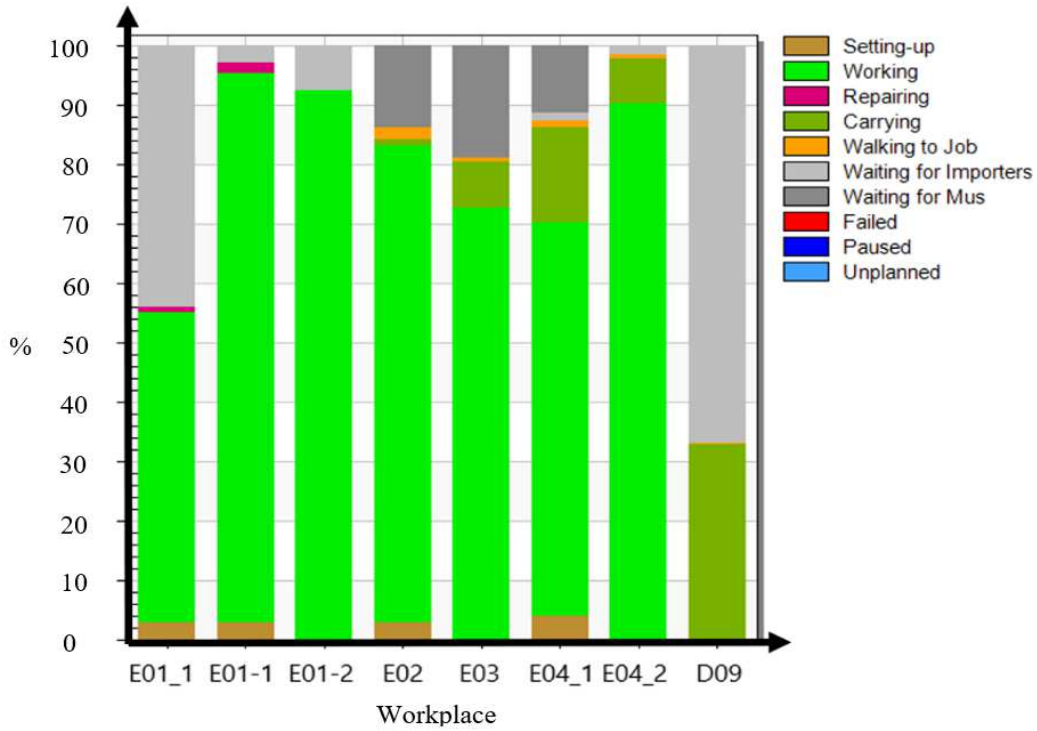

Figure 5 Chart of current worker's utilisation

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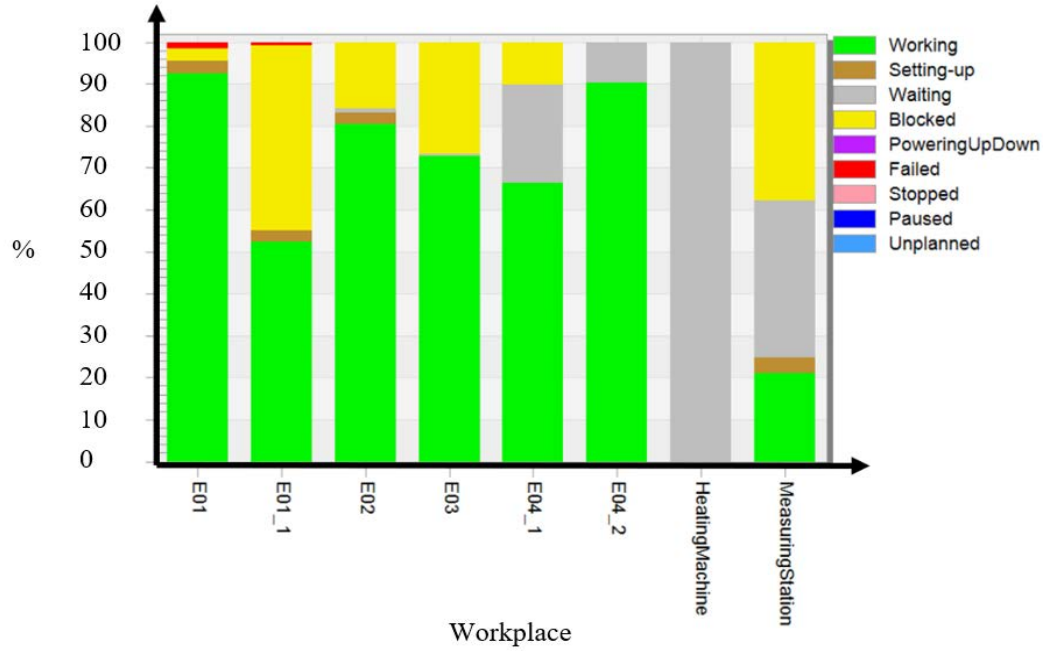

Figure 6 Chart of current workplace utilisation

From the resulting statistics, only in one case a minimum tact of the customer line was achieved, namely in merging the E01_1 and D09 workplace activities, which is not enough for the medium or faster tact of the customer line. However, there is the potential for testing in the distribution of activities. The next series of experiments is realised based on the distribution of activities so that the line is in reasonable balance. Experiment 12 is based on leaving the same number of workers. The worker from position E02 is helping in the E01_1 workplace, and one activity has been moved from the E01 workplace. Experiment 13 is an experiment without changing the number of workers. A worker from E02 is helping at the E01_1 workplace, where one of the activities of the E01 workplace has been moved. Also, the MeasuringStation and E04_1 were switched in this case. Experiment 14 is an experiment without changing the number of workers, and MeasuringStations, and E04_1 were switched. Experiment 15 is an experiment with changing the number of workers. A worker from E02's position is helping at the E01_1 workplace, where one activity has been moved from the E01. The MeasuringStation and E04_1 have also switched. The worker from the E04_2 are removed, and his activities are transferred to D09 workplace and worker. The switching of MeasuringStation and E04_1 is depicted in Figure 7.

Table 1 Experiments carried out to identify the possibility of merging workplaces and their activities

Experiment number	Workplaces whose activities are merged	Output [Pcs./hour]
Exp. 1	E01_1 and E02	**20.68**
Exp. 2	E01_1 and E03	**5.20**
Exp. 3	E01_1 and E04_1	**20.30**
Exp. 4	E01_1 and D09	**28.87**
Exp. 5	E02 and E03	**19.06**
Exp. 6	E02 and E04_1	**15.77**
Exp. 7	E02 and D09	**22.80**
Exp. 8	E03 and E04_1	**18**
Exp. 9	E03 and D09	**25.18**
Exp. 10	E04_1 and D09	**24.06**
Exp. 11	E01_1 and E02	**20.68**

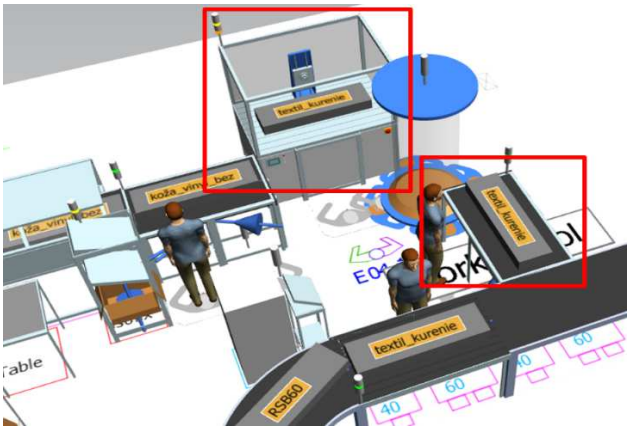

Figure 7 Illustration of positions after switching MeasuringStation with E04_1

Experiment 16 is an experiment without changing the number of workers. E01_Instal_LSHog worker from E02's position assists in the E01_1 workplace, where the E01 site has been moved, and the MeasuringStation rescheduling with E04_1 has been carried out. At the same time, the conveyor and E04_2 activities are transferred to D09_1 and D09_2. The depiction of the location of the completed conveyor is in Figure 8.

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Figure 8 Illustration of the position of the supplemented conveyor

Table 2 shows the experiments and results achieved.

Table 2 Experiments and their impact on hourly line performance

Experiment number	Output [Pcs./hour]
Exp. 12	**30.74**
Exp. 13	**30.27**
Exp. 14	**30.14**
Exp. 15	**31.04**
Exp. 16	**32.87**

A Figure 9 graph is created to better understand and interpret the experiment's results.

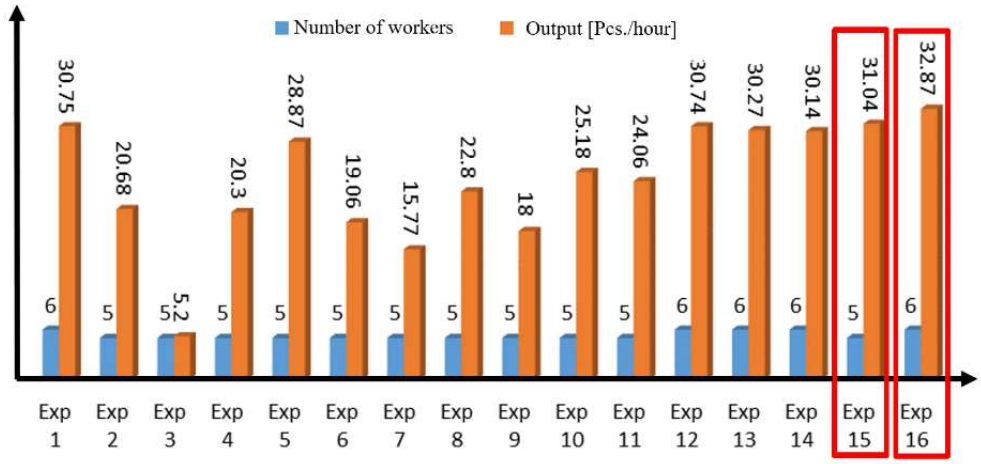

Figure 9 Summary graph of experimental results

In the graph in Figure 9, two experiments 15 and 16 are marked. If we consider reducing the number of workers and, simultaneously, the highest possible output, then the result from experiment 15 is optimal. If we consider streamlining the line to cover even faster tact from the customer line, then the solution from experiment 16 is best.

4 Conclusions

In the current market competitive environment, the success of each company depends on the ability to adapt, which is a prerequisite for satisfying customer requirements. Each competitive company examines its processes to make them more efficient so that it ultimately obtains an increase in production or reduces waste of resources (e.g. materials, raw materials, capacities, money). In assembly processes where there is a time follow-up, the height of times along the line must be balanced, and the bottlenecks must minimally affect the final output. Sometimes such bottlenecks can be detected normally by looking, especially if there are buffers in the system that display this state. However, if the line has no buffers in which pieces accumulate, the bottleneck locations without a time study are more difficult to detect.

Computer simulation helps to detect bottlenecks of the reasons for their emergence as well as follow-up problems. A simulation model that is properly validated by the actual system helps us verify our decisions without intervening in a real system. Most bad decisions are characterised by the fact that their correction or retention has a negative impact on production as well as costs.

The article aims to describe the use of simulation carried out in the framework of the simulation study and the results achieved. The study was implemented using a computer simulation realised based on general simulation study methodology to increase the efficiency of the assembly line in the company. The case study described in the article used a simulation tool, Siemens's Tecnomatix Plant Simulation 15.2, to perform computer simulations. As part of the solution, the essential requirement from the corporate hypothesis that there is such a new distribution of workers and activities where there will be an increase in performance was met. Two proposed variants, where one allows the number of workers to be reduced by one worker

and meets the requirements for medium and slow customer tact of the line by better organisation and logistics, match this hypothesis. At the same time, performance will improve by 0.94% by using this variant. A faster customer tact can be achieved without reducing the number of workers, and performance might increase by 6.89%. The proposed simulation study methodology is especially suitable for companies with essential data and layouts and needs to verify their optimisation solutions associated with investment costs.

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Methodologies for characterization, evaluation, and improvement of logistics in the food supply chain
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Methodologies for characterization, evaluation, and improvement of logistics in the food supply chain

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Abstract: The food supply chain (FSC) is made up of producers, traders and processors who bring the product from supply to demand through logistical processes**.** Food supply chains require specific methodologies for their current diagnosis, evaluation and improvement. Logistics in food supply chain requires to be managed according to its nature. This article identifies the different methodologies through a systematic literature review of publications from 2005 to 2022, using Web of Science, Scopus and Google Scholar search engines, in order to establish the state of the art. As a result of this review, a new taxonomy is proposed and includes the following methodological groups: management, qualitative, quantitative, multi-criteria decision-making (MCDM), statistics, machine learning, mathematical modelling, discrete simulation, system dynamics and others. The methodologies of characterization, evaluation and improvement are classified into two main groups of logistical means and modes. The performance measures most commonly used in the methodologies by the researchers were also identified. From the article, discussions, challenges and trends are generated to identify possible future research and different gaps.

1 Introduction

The characterization establishes an informative and/or descriptive study to establish the situation of logistics in the food supply chain (LFSC). Moreover, the evaluation compares LFSC current status against desired performance measures. In terms of improvement, the aim is to bring logistics in the FSC to a higher performance state.

The logistical modes or processes about how to manage supply, inventories and storage or distribution are relevant in food supply chain; its analysis must consider changes in temperature, relative humidity, perishability, short life cycles, these elements define the use logistical means or resources to be used, such as facilities, transportation, packing and packaging, storage , information and traceability or systems of integrated enterprise resource planning (ERP) from the supplier to the final consumer, as well as government policies, food security, and the effects of natural disasters on food. The means and modes in the LFSC ensure the operation and give rise to the network design, so it is necessary to characterize, evaluate and improve, considering variables, parameters and performance measures such as efficiency, responsiveness and quality [1]. The interaction of each element on the FSC and the relationships between its different agents generate information flows in foods that give rise to designs, which require different methodologies to diagnose, evaluate or improve the LFSC.

The activities that take place in the FSC and logistical processes and resources, the population heterogeneity and uncertainty, are continuous progress elements [2]. The vertiginous market's change requires methodologies and models adjusted to the logistic process, the life cycle and conservation, food transportation with temperature and risk control [3], reverse logistic [4] and the reduction of bullwhip effect [5,6]. Food safety, lack of quality in food supply and the waste generated in the FSC links are caused by shortcomings in logistical modes and means management [7], as reduction of resources and waste generation without proper treatment [8], lack of communication between producer, processor, intermediaries and the consumer, losses due to spoilage from handling, perishability or inadequate structure of the FS, adding also government policies on export and import in a global market [9]. This results in a failure to implement FS management that impacts on quality, food safety and sustainability [10], which significantly reduces the shelf life of food [11], weakening the FSC links in times of disaster or pandemic [12].

Due to these FSCs issues and their logistics processes, there is a need to establish the commonly used methodologies in characterization, evaluation, and improvement for LFSC, their trends and challenges, as well future research. In this systematic literature review, journals information is analyzed to establish the state of art of the most used methodologies.

2 Methodology

The systematic literature review of LFSC characterization, evaluation and improvement methodologies carried out in: Scopus, Web of science and Google Scholar. A database compiled from 26 research journals was generated, with 123 articles in total, showing that the largest article's number were from databases as Elsevier, Emerald, MDPI, Springer Link and Taylor & Francis. Each article's contribution is considered according to citations, specialized authors, as also seminal, theoretical, and practical articles. To get the information, research included main words, support words and connectors as shown in Table 1.

Table 1 Research methodology

SEARCH	MAIN WORDS	SUPPORT WORDS	CONNECTORS
Scopus	Food Supply Chain - Methodology - Logistics	Characterization – Improvement - Performance - Evaluation	And - Or
Web Of Science	Food Supply Chain - Methodology - Logistics	Characterization - Improvement - Evaluation - Performance	And
Google Scholar	Food Supply Chain- Logistics - Methodology	Characterization - Improvement - Evaluation	And - Or

**Acronyms of words used in the search: Food Supply Chain (FSC), Methodology (M), Logistics (L), Characterization (C), Improvement (I), Evaluation (E), Performance (P)*

The following questions were formulated to guide the systematic literature review: What are the methodologies for diagnosing, evaluating and improving the FSC? What are the characteristics of these methodologies? What are the performance measures used in these methodologies?, and, What are the discussions, trends, challenges and future research regarding the diagnosis, assessment and improvement of FSC?. The information was consolidated according to approaches, topic and specific points regarding LFSC, classified into subtopics, the relationship to logistics areas and social, economic, environmental, or governmental impact. The methodological design steps are presented in Figure 1.

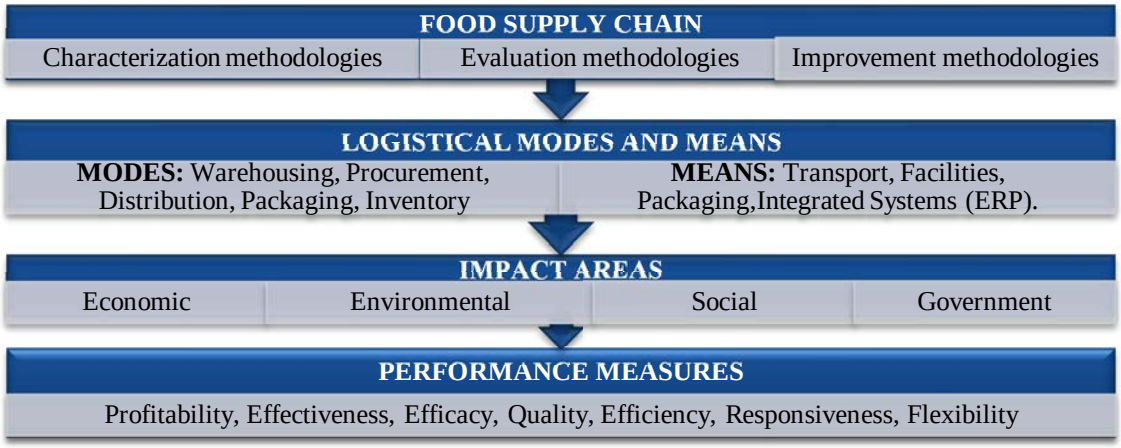

Figure 1 Taxonomy for the analysis of methodologies

The methodologies found present an approach to methods such as decision-making, quantitative analysis, qualitative analysis, and techniques, using different theoretical models and conceptual frameworks. Finally, a taxonomy of performance measures is developed. The methodologies are evaluated chronologically and research trends in LFSC are identified.

3 Methodologies for Characterization, Evaluation, and Improvement of logistics in food supply chain

Based on the systematic literature review, relevant thematic axes were identified for FSC study, some belong before 2010. Those related to current environment dynamics appear from 2017. In India, since 2017, contributions have been made towards integrating FSC with logistics and sustainability through the promotion of new and emerging technologies to address challenges in food security. In China, Turkey and UK, they focus on the use of technologies for traceability, sustainability, and quality, considering different risks in FSC, due to dynamism, environment variability and food life cycles. In Italy and in line with FAO guidelines, the focus is on logistics as a FSC fundamental process for quality and food safety.

In Australia, they focus on use of technologies addressed on risk, vulnerability, and logistics (Imran Ali). Wageningen University in the Netherlands focus on food security and sustainability, where Van der Vorst and his

team study FSC and Logistics. Based on the systematic literature review, the classification shown in Figure 2 is proposed, according to each topic and publishing year between 2005 to 2022.

The methodologies compiled in literature are proposed by the authors according to the environment, the complexity of SC management, the characteristics of different foods to be analyzed, the performance measures used, integration level between stakeholders, the logistical processes, as also experience and knowledge of the studied system.

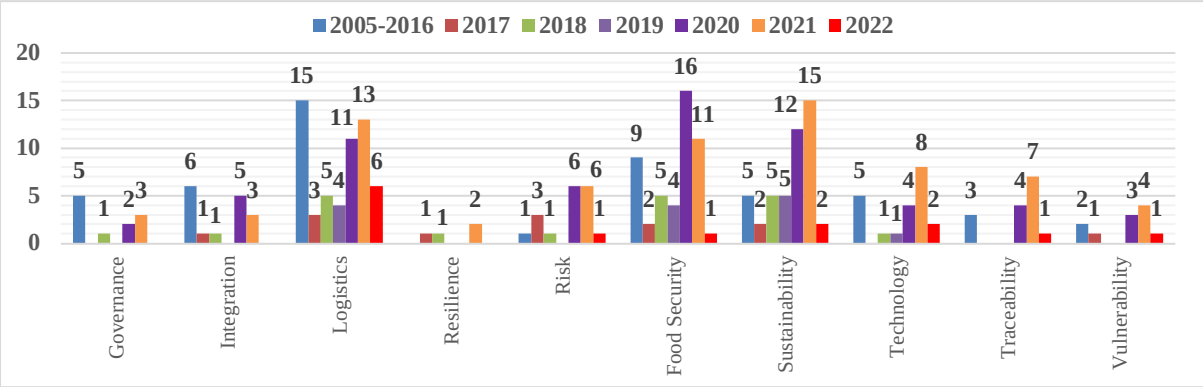

Figure 2 Years versus thematic axes

To establish an appropriate methodology involves proper communication between the parties [13]. The information, logistic and productive flows of the FSC must have connection and coordination, global analysis, responsiveness, reliability and competitiveness, being able to measure and evaluate performance [14].

Identifying the processes involved in the LFSC requires a methodology that works according to the current dynamics, sizing the activities and evaluate the conditions that favor or not their performance [1]. The characterization, evaluation and improvement of the LFSC are linked to the design and configuration of the flows of each of the processes that make up the LFSC [15,16]. The comparison with different SC models or schemes and logistics processes allows establishing a frame of reference and performance measures that determine the past, current and future status. Although the search for economic-financial performance is mainly evident, social, political, environmental and sustainable approaches to CS are appearing [17].

With logistics as a vital axis to proper management supply chain [18], the main methodologies used and the fundamental aspects of each one of these methodologies are presented below, based on the logistic modes and means found in the literature review. The articles consulted on characterization, evaluation and improvement were case studies and development of models that build concepts or constructs and allow modeling of FSC.

3.1 Characterization methodologies

The characterization of the LFSC is done analytically or empirically and details each aspect according to the authors' environment. In Table 2, methodologies are divided into management, qualitative, MCDM and statistical.

Table 2 Logistical modes and means in Characterization methodologies

		Management	Qualitative	MCDM	Statistical
MODES	Storage	2	3	5	4
	Supply	0	0	2	4
	Distribution	5	6	2	4
	Packaging	0	1	3	2
	Inventories	0	0	3	3
MEANS	Transport	7	5	6	4
	Packing	3	3	1	1
	Facilities	3	1	3	2
	Enterprise Resource Planning Systems (ERP)	0	0	1	0

3.1.1 Management methodologies

They aim to improve the practices of business processes interacting in the SC. The Balanced Scored Card (BSC) methodology uses costs related to transport, distributions, and deliveries [19]. SCOR is also used, in which the main factor is logistics, facilities and the formulation of sustainable production plant scenarios [20]. The Global Supply Chain Forum (GSCF) methodology generates twenty-four logistics activities for each key FSC business process, integrating supply chain management

(SCM), logistics, business processes, product flow, reverse logistics, logistics risks in cold chain, packing and transport resilience [21], the identification of relevant attributes to describe and represent FSCs with different perspectives or narratives [22].

There are methodologies that work with quality at the core, risks with respect to logistics facilities are addressed through a methodology based on the Quality management model [23], combining quality and risk measures including product lifetime in transport activities [24]. Another approach is structural quality modelling of perishables by analyzing suppliers, customers and logistics processes [25]. Other methodologies [26] work with diagnostic tools such as food safety management system, quick scan audit (QSAM) focused on chain uncertainty addressing material flow in distribution processes, facility analysis and equipment modernity. Empirical models propose activity performance measurement systems, PMS, including real-time transport [27-29]. The reference methodology RAPDtT (Receiving-Storage-Processing-Dispatching-Internal and External Transport) provides a roadmap through a process diagram and covers the logistics operation [30]. Addressing problems holistically is possible in environments of uncertainty, as is the case with the soft systems methodology that is proposed in aspects of sustainability, values and ethics, a more humane perspective, and cooperation-oriented [31].

3.1.2 Qualitative Methodologies

They rely on qualitative collection data and analysis, flexible semi-structured interviews, matrices, and tables to describe and contrast one or more specific characteristics in LFSC. In a research study [32], they propose a risk matrix that evaluates how company size and its links affect the performance, the traceability system consistency in storage conditions and packaging quality. Multi-criteria performance matrices can be used for decision making in distribution [33]. A mixed method is developed with data interviews qualitative and survey quantitative data analyzed in SC by combining contingency theory methodologies and resource-based theory [34]. In countries such as Vietnam, for short food chains development between farmers and distributors, semi-structured interviews have been used to achieve price stabilization, sustainability and decision-making in situations such as COVID-19, issues affecting smallholder farmers [35]. Likewise, expert stakeholders in fish SC have used information systems and technology for facilities and transport with cold requirements [36].

Impact and challenge tables are used to measure and characterize the technologies impact as internet of things, blockchain, big data and artificial intelligence, defining faster and cheaper delivery options in distribution centers and limited storage scalability [37]. The relationships with the FSC links can also be characterized by the PPT methodology (People-Process-Technology) where the blockchain ensures the measurement of food authenticity through traceability in storage, transport and distribution [38] and packing [39]. RFID radio frequency technology is used in distribution centers, packing processes and inventory levels with traceability for the recall of unsafe products in the reverse LFSC, using cause and effect analysis methodologies from current Food, Drug Administration and USDA regulations [40].

Content analysis is used through literature review to study sustainability in FSC and the importance of economic, social and environmental aspects in distribution and packing [41]. In a social approach, a FSC of artisan producers is observed using the methodology of content analysis, information gathered through interviews, documentary analysis and direct observation, in commercial spaces, meetings with suppliers, product dissemination, marketing and transport [42].

3.1.3 Multi-criteria decision-making (MCDM) methodologies

These methodologies help to have a more detailed characterization perspective with information generated mainly by experts. They allow observers and experts to understand issues of some complexity to make decisions from different perspectives. The Analytical Hierarchy Process (AHP) has been used to determine parameters that affect the FSCs sustainability where packaging and packing have a direct impact in terms of reuse and recycling [43] in energy consumption in industry structure and gas emission in the FSC [44]. The AHP methodology can be combined with Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) to define storage, facility and transport risks caused by poor food handling, and thus be able to make good decisions on waste reduction [45], studying the efficiency of technology management in the FSC to ensure shelf life. TOPSIS together with the Elimination et Choix Traduisant la Realité (ELECTRE) methodology and the cross efficiency method (CE) serve to rank the countries with the most cereal exports to the US, identifying multi-criteria risks in socio-economic and institutional conditions in terms of food safety and transport [9].

The interpretive structural model (ISM) segments the information and develops organizational or hierarchical processes, and has also been used to analyses risks generated by 3PL in the coffee LSC, the success factors related to storage and transport, integrating expert information through the MICMAC and Fuzzy TOPSIS methodologies to priorities risks [46]. With regard to sustainability in perishable FSC in developing countries, the ISM methodology was used in conjunction with the analytical network process (ANP) to identify and model economic development, including infrastructure, adequate cold storage facilities and waste mitigation [47]. The ISM methodology is also used with the MICMAC cross-impact matrix to determine the causes of food loss in transport, inadequate packaging, poor storage facilities and lack of

information exchange in the fruit SC [48], as well as to identify causes of post-harvest losses in 3PL transport [49].

For the elaboration of an integrated performance measurement framework and the interdependence of criteria including transport and storage, a hybrid method of Fuzzy with MCDM (multi-criteria decision making) is used [50]. Methodology based on the Fuzzy-DEMATEL (Fuzzy Decision Making) interpretative structural model together with the Fuzzy-DELPHI methodology, identify and analyze the elements of FSC and its risk dimensions in sustainable aspects, pollution produced in storage, transport and distribution [51]. Besides, the Best Worst Method (BWM) methodology is applied to evaluate alternatives for sustainable decision-making in a flour SC with inadequate storage systems that cause quality loss [52]. With methodologies such as MAUT (hybrid multi-criteria model between the multi-attribute approach) and PROMETHEE (preference ranking organization method for enrichment evaluation) determine the suppliers sustainable performance and propose improvements in FSC management [53].

3.1.4 Statistical methodologies

The information collected in statistical studies is based on activities such as interviews and structured questionnaires that allow capturing useful and necessary data for the respective statistics. Demographic statistics are used in the interest of understand the different actors integration impact in FSC, in cold chain context [54], for data recorded from demographic surveys, time series are also used to show behavioral patterns, in this case, of the impact of supply and transport on the pandemic [12] or, with regression, to assess risk elements with their probabilities and consequences on LFSC and infrastructure [55]. Structural equation modelling is also used to estimate causal relationships between variables, whit regard to understand raspberry chain fragility affecting safety in the storage, distribution and packaging processes [56,57] applies it in a sustainable management with traceability context.

In some cases, several methodologies are used to improve results. Thus, structural equations interact with other methodologies such as exploratory factor analysis, allowing for greater precision in the experts' observations. In sustainable environments and associations involved in distribution [58] or, distinguishing factors affecting these interorganizational relationships in a vertical coordination [59]. Structural equations with resource-based theory allow exploring the impact of traceability on food packaging [60].

Other statistical techniques used for the characterization and processing of FSC data are logistic regressions. Thus, statistical techniques focused on a literature review as topic mapping, co-citation and co-authorship were proposed in order to address issues related to sustainability and new technological challenges [61]. On the other hand, there are methodologies that perform monitoring with statistical control processes (SPC) and allow distinguishing variations that may alter the FSC, being applied in the diagnosis of the economic impact of inadequate management of the cold chain in supply and storage [62].

3.2 Evaluation methodologies

The literature includes mathematical modelling, machine learning, simulation, system dynamics, quantitative methodologies and other methodologies, shown in Table 3.

Table 3 Logistical modes and means in Evaluation methodologies

		Mathematical Modeling	Machine Learning	Discrete Simulation	Dynamic Systems	Quantitative	Other
MODES	Storage	2	2	1	1	1	0
	Supply	0	0	0	0	1	0
	Distribution	1	2	2	2	2	2
	Packaging	0	0	0	0	2	2
	Inventories	1	1	1	1	2	1
MEANS	Transport	3	2	3	1	4	2
	Packing	0	1	0	0	0	1
	Facilities	1	2	1	1	1	0

3.2.1 Mathematical modeling methodologies

Lineal programming models evaluate different environments; in [63] they develop a multi-objective VRP model for last-mile perishable fruits, in order to reduce organoleptic properties loss caused by congestion in megacities. On the other hand, the use of fuzzy integral assessment was found to evaluate the risk of food quality for the consumer, due to contamination in storage and transportation, so it is necessary to consider different controls on temperature, inventories and technologies. [64]. Likewise, data envelopment analysis (DEA) used to evaluate performance of genetically altered foods with respect to transportation fuel costs [65,66] evaluates tradeoffs in Biodiesel chain design by means of a multi-objective optimization model. Game theory is also applied at the environmental level in decentralized or non-

decentralized decisions between a cooperative company and consumers, considering transportation, optimal order quantities and environmentally sustainable processing [67]. Mathematical optimization is used to assess both economic and environmental feasibility with respect to waste and costs incurred, for example, in logistics facilities [68].

3.2.2 Machine learning methodologies

They are used to evaluate a large amount of information and obtain optimal results more efficiently, quickly and with greater precision. In turn, [69] evaluate the sustainable LFSC of grapes, propose a system of risk assessment indices through the methodologies of an optimized BP neural network (back propagation neural network, GABP and PSO-BP). In this case [70] applied a simulation and numerical analysis methodology to evaluate the incurred risks in strawberry cold chain, analyze factors affecting quality and food safety in fresh produce, including technological, biological, environmental and emergency risks in storage, facility management, distribution, and transportation.

3.2.3 Discrete simulation methodologies

This group includes articles that have used discrete simulation, such as that developed by [27] which evaluates transportation costs between different modes, shrinkage reductions and temperature control in food distribution using an ALADIN (Agro-Logistics Analysis and Design Instrument) simulation environment specialized in the food industry, while [71] studies factors that influence the horizontal collaboration of a horticultural SC, with transportation being the most important. Another aspect is the use of technologies, in [72] present the CAS (complex adaptive system) to evaluate food safety in a FSC, and it allows to understand the problems in the distribution with the RFID use.

3.2.4 Dynamic systems methodologies

These methodologies are used to analyze dynamic environments, in the paper [73] evaluate the capacity of future vehicle routes for the potato SC, in [74] the effects of multimodality are evaluated on the perishable FSC logistic performance, on the other hand in [75] evaluate the design of the perishable FSC in food safety and logistics, and finally on [5] evaluates the impact of traceability on bullwhip effect.

3.2.5 Quantitative methodologies

The most widely used is product life cycle assessment (LCA). In [76], authors evaluate the material costs that affect the FSC of perishable goods in order to achieve sustainability. In [77] a SC of biscuits is studied using LCA to address issues such as environmentally sustainable packaging and transport to reduce emissions and distances. Regarding the evaluation of sustainability processes in global and short CSA, in [78] they use LCA to evaluate inventories, transport, storage and distribution. In the case of [79] they study perishable foods such as tomatoes and consider transport and packaging for the quality of the final product. The research carried out in [80] evaluates transport and supply by means of an ecological last-mile transfer system with hand carts and bicycles, quantifying demand, supply, and market situations, by means of a feasibility study.

3.2.6 Other methodologies

The DEMATEL Methodology is used in decision-making processes by analysing interdependence between different components, and in the case of FUZZY-DEMATEL it allows to build and evaluate interrelated structural models with cause and effect by identifying sustainability drivers such as transportation, using the supply network to meet customer requirements [81]. For processes in the agricultural FSC related to sustainability, [82] uses the Fuzzy-DEMATEL and model a multilevel system, managed with different emerging technologies application, internet of things in a COVID-19 environment, and evaluating the intelligent packing of agricultural products.

TOPSIS in a fuzzy environment and together with set theory are used to define which information systems to use in LFSC and to assess compliance with traceability requirements in current legislations [83]. For expert-based models [84] combine DELPHI and mode-effect analysis to evaluate the impact of change drivers such as food security packaging vulnerability in an aquaculture chain.

In another paper, Chan and Qi 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) [85].

3.3 Improvement methodologies

These methodologies represent systems with different models to develop improvements in aspects such as the use of technologies, cost reduction or vulnerability in FSC, among others. They were classified into means and modes vs. mathematical modelling, system dynamics, simulation and other methodologies, Table 4.

3.3.1 Mathematical modeling methodologies

The mathematical modelling found presents different improvement strategies in FSC. In [86] studies supply, transportation and distribution, optimizing logistics costs and quality associated with storage and refrigeration in environments of uncertainty and variability. Faced with situations in volatile and changing environments, [87] studies the resource utilization vulnerability, costs and operational risk through the traceability model with a quality and food safety perspective. With mathematical modelling, [88] analyses the RFID impact with a newspaper vendor model and the benefit of reducing inventory losses in a FSC. [89] evaluates RFID technology

with QR, GPS and Blockchain used in traceability, for quality and cost improvements, through contract coordination policies, is applied to fresh chicken FSC. On the other hand [90] contextualizes FSC with the objective of improving farmers' incomes through product quality, storage and transportation.

Improving the perishable FSC network with transportation and distribution centers for better performance is being studied by [91], where evaluation uses a mixed integer linear programming model. In [92] proposed a sustainability model that lowers the costs of implementing rail-road intermodal transportation for perishable foods and reduces carbon footprint.

On the other hand, [93] proposes a multi-objective IRP model (inventory-routing-problem) for improving distribution performance in a FSC. In [94] a multi-objective, multi-scale, multi-product model developed from mixed integer linear programming proposed to improve a perishable FSC with seasonality in a developing country in order to design the logistics network, contemplating packaging, transportation and storage and allowing the actors to approach the efficiency frontiers. [95] proposes a LIRP (Location-inventory-routing problem) model with mixed integer linear programming, decreasing distribution costs in small farmers for fresh FSC, is solved with genetic algorithms and Lagrangian relaxation. Meanwhile, [7] proposes a multi-objective optimization model for FSC network design to improve food availability and access.

Table 4 Logistical modes and means in Improvement methodologies

		Mathematical Modeling	Discrete Simulation	Dynamic Systems	Other
MODES	Storage	3	1	1	0
	Supply	2	0	0	0
	Distribution	6	2	1	1
	Packaging	1	0	1	0
	Inventories	4	1	2	0
MEANS	Transport	7	2	2	2
	Facilities	1	1	0	2

3.3.2 Discrete simulation methodologies

In [96] a graphic interface is developed to reduce delivery times in the agro-industrial sector to reduce costs and increase efficiency. Through simulation, it shows a decrease in fuel, maintenance, and tire costs during processes such as transportation and distribution. In [97] they propose business models with the use of technologies, interconnected electronic networks of grocery stores looking for sustainability, minimize food waste through inventory management and distribution, the simulation showed better results in an internet of things environment. Based on the application of value chain mapping supported in food losses reduction in FSC [98], a model with different simulation scenarios is made to improve sustainable processes in logistics, storage, transportation and facilities.

3.3.3 Dynamic systems methodologies

A model that allows product quality characteristics to be preserved is presented by, through system dynamics is improved by reducing food waste in excessive inventories and inadequate quality, to maximize retailer profits through pricing, based on the shelf life of food. The paper [99] evaluates external integration mechanisms for the improvement of fruit FSC, in [100] is evaluates better packaging management in transportation and storage in fruit FSC. On the other hand, [101] analyses different structures for perishable FSC design with the dynamic system paradigm, taking into account inventories and transportation to obtain better logistic performance. In [102] evaluates traceability systems for better performance of FSC.

3.3.4 Other methomologies

Using Fuzzy-DEMATEL and Fuzzy-AHP techniques, in [3] they evaluate the improvement of food quality in cold transport and the search for suitable 3PL and facilities, and identify criteria to reduce losses in SC of fruits and vegetables. [13] employs ISM and DEMATEL technologies, developing an efficient system based on internet of things that improves the coordination mechanism, to optimizes and automates the agricultural infrastructure. [103] explores the possible strategies in perishable FSC to improve their resilience, using Best-Worst Method (BWM), correlate them with Quality Function Deployment (QFD), to maintain the flow in distribution and transportation from farmer to consumer in an uncertain trading environment during COVID-19.

3.4 Performance measures

There are several performance measures found in the literature. In [29] authors identify flexibility, responsiveness, efficiency, quality, effectiveness, efficacy and profitability for LFSC. These measures are used in the LFSC performance evaluation of all parties involved, their interdependence is analyzed by [50] , while in [32] they study how the size of the company impact sustainable performance, on the other hand [58] pose measurement models that evaluate partnerships in FSC and [39] evaluates the blockchain in FSC performance.

Flexibility in FSC is related to several aspects such as the links or agents ability to make decisions under an uncertainty environment [31] , the use of technologies such as ERP in planning and risk analysis for decision making [24]. As for responsiveness in LFSC, it is measured with respect to sustainable packaging and packing, storage, distribution and transportation [64],and horizontal collaboration of producers by sharing information in order to meet demand [71]. In the article [63] FSC design is evaluated and its impact on the preservation of organoleptic properties and reduction of losses, improving food availability and access.

The efficiency of FSC is mainly related to economic aspects, which is reduced due to losses [94], improved through the control and assurance of the cold chain [56] and the adequate temperature management in transportation [92] or logistic processes [98]. Also through the use of EDI (information exchange) in the FSC [104]. For its part, Profitability is related to the economic performance that allows the growth of the FSC, in which case costs [105] and recently the environmental impact [89] or operational risks [87], or associated with food safety [106] are considered. While effectiveness in LFSC is related to the business environment, in the achievement of goals or objectives [21].

Perhaps quality is the most used performance measure in the LFSC, where in [107] they study the risks in safety and uncertainty [67], including according to ingredients quality or green agroecological products and [57] environmental, while [101] studies the food safety, in [36] the sustainability or the impact of technologies in traceability. Sophisticated techniques of temperature controls in the cold chain are also found in[62], presenting in [84] the vulnerabilities of the change in the performance of salmon FSC. In paper [25], quality related to social and [90] business integration factors. Figure 3 show the use of performance measures depending on each type of methodology, being characterization, evaluation, and improvement.

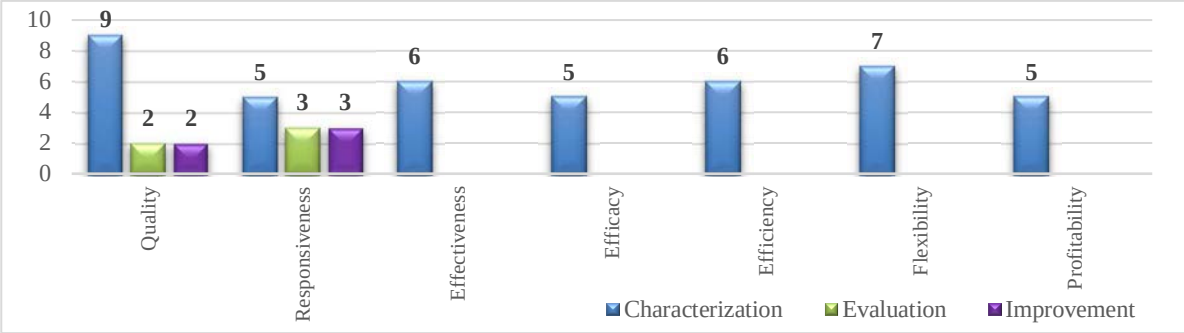

Figure 3 Performance measures vs. Characterization, Evaluation, and Improvement methodologies

4 Discussion, challenges and trends

FSC faces several challenges regarding environmental, social and economic sustainability, in accordance with the Strategic Framework for 2022-2031 [108]. The responsible use of resources, proper solid waste management, environmentally friendly, recyclable and reusable packing [52], and logistic means that avoid losses, the use of means of transportation that avoid increasing the carbon footprint, with the use of appropriate technologies and strategies for transportation (land, air or sea) and storage, contribute to risk mitigation [23], to the durability of food in the market and the environment, especially with temperature control and other preservation technologies, using technologies that maintain the product life cycle, with cooling and preservation processes, so that the food reaches the final consumer in safe and quality conditions. Food safety must be guaranteed. Food produced organically, without preservatives or additives, is becoming increasingly important.

LFSC has different challenges to face; during the life cycle, logistics processes influence the physical-chemical, organoleptic and biological characteristics and alter the conditions in which food reaches the consumer [77], which affects the performance of the FSC. [54] and [109] lead companies to hire 3PL logistics operators and use specialized logistics platforms [110]. Businesses must make decisions that help LFSC compliance and generate a positive impact [111] and a proper FSC management [112].

Organizations should carry out horizontal logistics practices that allow collaboration, information flows and address problems such as variability and risks present in FSC [71]. In the FSC, the links must be integrated [99] through co-regulation, coordination [113], government policies in favor of contributing to food safety [114], in compliance with norms, standards and logistic customs of the countries [115,116]. With respect to economic, social, environmental and governmental aspects, a balance is sought between demand, supply and food flows and associated information in logistics processes [1], as well as the search for sustainable objectives at strategic, tactical and operational levels [37].

Use of technologies that facilitate interoperability for decision-making by chain actors in real time [88], better quality conditions are achieved, generating controlled environments that contribute to food safety, risk mitigation and information control with traceability systems in the SC

[117]. The use of new technologies in the information era, make LFSC to modify and adapt according to the dynamics of the environment [95]. The evolution of technology that brings with it paradigms [118] that in conjunction with the logistics 4.0 concept [34,119], allows better traceability [120]. The storage with cold chains and using RFID (radio frequency identification system), WSN (Wireless sensor Networks or sensor network), EPC (electronic product code) and integrated blockchain; which allow the updating in real time information and improve responsiveness in LFSC [120-122], for large number of data [97,123].

In the above context, the characterization of LFSC requires the use of methodologies that allow establishing their heterogeneity and particularity, specifically of perishable products with different life cycles, short chains, in changing environments. The evaluation of performance requires a combination of modeling techniques to reflect the dynamics of LFSC and proposals for improving scenario evaluation strategies that represent reality, uncertainty, and risks in vulnerable environments such as pandemics.

Developing countries have many small producers in the first mile and traders in the last mile, generating modeling challenges for the design of the FSC network and its logistics. Considering the efficiencies of territorial proximity and the integration of the different links of the FSC, logistics clusters and productive chains. Transportation in the FSC in a fast and efficient way, with delivery routes so that it arrives correctly and in the established times, from the first to the last mile. For this purpose, advanced multi-objective and multi-link mathematical optimization and simulation models that approach the behavior of reality and include dynamics, uncertainty, risks, resilience, require new solution methods. And finally, the use of new strategies such as multimodal transportation, technologies application as RFID, Blockchain, Internet of Things, environment simulation processes and even methods application as Machine Learning that seek sustainability.

5 Conclusions

In this systematic literature review, different characterization, evaluation, and improvement methodologies in logistics in food supply chains (LFSC) were found. Through the evaluation of 123 articles, obtained from Web of Science, Scopus, and Google Scholar, proposed a taxonomy to management methodologies, qualitative, quantitative, MCDM, statistics, machine learning, mathematical modeling, simulation, and system dynamics, also grouped in logistics means and modes.

The need to include sustainable performance measures, in economic, environmental, and social aspects, complemented with logistics measures are identified as trends. Methodologies should allow to assess application level of modern technologies as traceability systems, internet of things, blockchain, logistics 4.0. The evaluation models and improvement proposals are of diverse types: optimization, simulation, management system dynamics, multi-criteria, analytical, qualitative, quantitative, or statistical. The challenges of these evaluation methodologies are to include elements that are closer to a changing reality, with uncertainty and risks, and it is necessary to develop multiobjective multilevel, multi-link and/or stochastic models. These methodologies should contemplate specific aspects of LFSC, such as varied life cycles, perishability, losses, organoleptic and physicochemical characteristics of food, cold chain, control, and monitoring of quality in real time.

Gaps between first and third world countries hinder research applications due to deficiencies in land routes and distribution networks, transport methods, problems of corruption and lack of government policies, investments for the improvement of perishable FSC, waste, excessive costs, and losses in the flow of food.

Despite the substantial differences found between the different food chains, this article provides an overview that potentially serves as a basis for researchers in future work on methodologies to characterize, evaluate or improve LFSC.

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A new model for cost estimation construction project using Hybrid importance regression ensemble method
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A new model for cost estimation construction project using Hybrid importance regression ensemble method

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Keywords: cost factor, Importance Regression Ensemble Method, K-Nearest Neighbor Method, construction.
Abstract: Cost estimating entails gathering and evaluating historical data, as well as using quantitative models, methodologies, tools, and databases to forecast the cost of a program in the future. At the early stages of the building design process, the cost is considered one of the most important elements in making decisions. During the design phase of a project, cost estimating is quite essential. To compelet a construction project successfully, it is critical to design a usable model and method for cost estimation in construction projects. For the above reason, this study has developed a hybrid method to conduct an accurate cost estimation in construction projects in Iraq. This study also conducted a rigorous survey to find five main influential factors with thirty-six sub-factors in the Iraqi market. It was evaluated through previous studies, questionnaires, and surveys of twenty projects to build a matrix factors database for construction projects. This work gathered the construction cost factors from relevant research and expert views. In the second step, the researcher ranked the factors within the Importance Regression Ensemble Method then the K-Nearest Neighbor Method was applied to specify the effect of the near-effective factors on the cost. The outcome of this study will be helpful to construction professionals in estimating a construction project effectively.

1 Introduction

Estimating building costs is a crucial step in the construction process. The estimation is also very important logistics support of a construction project to meet the demand of the requirment of the project. It represents the total sum needed to cover the expense of everything that must be acquired in order to carry out the project. Preliminary estimates of costs based on conceptual designs are accurate for these two reasons. To begin, the estimates are only as strong as the sloppy, incomplete information used to create them. Second, the building's characteristics and its price tag are more amenable to change early in the design phase than they are later. These considerations motivate studies of development models based on different methods and techniques that might improve conceptual cost estimations [1]. The price of building work must account for direct expenses, indirect costs, and profit. In order to determine how much a job will cost, contractors might utilize unit pricing. The contractor's significant expertise is required for this technique. The unit price must account for all of the aforementioned expenses. It is common practice to calculate direct costs (labor, materials, and equipment), indirect costs (labor, materials, and equipment), and profit margins separately when making an estimate of total costs [2]. According to EL-Sawalhi (2013), the most prevalent types of cost estimations are [3].

Estimate models

In cost estimating, three models are defined based on the level of depth of the output information, time and resource availability, and the stage of the construction life cycle in which they are primarily developed, as shown below [4]:

1. Models based on mathematical underpinnings have unquestionably progressed as computing techniques have improved. In this regard, different estimate models based on probability, fuzzy set theory [5], or regression estimating models exist in the construction sector to assist estimators in selecting the cost model based on historical data for a certain cost estimating application [6].
2. Activity-Based Costing Models: This seems to be the most realistic model since all overhead expenditures can be attributed to the specific activities that need them. To be more specific, the construction sector may benefit from the ABC technique by defining and categorizing all the activities and operations necessary to generate each construction work unit, and then examining, in each instance, all the aspects that impact its cost. When construction firms have this information ahead of time, they are better able to manage their financial investment on the job site, regulate expenses, and do cost-benefit analyses at various stages of project development [7,8].
3. Input-output analysis is the basis of process-based cost (PBC) models. The primary output of the construction business is the physical structure that was built, while the necessary inputs are the materials that went into its creation. PBC models are able to synthesize the parts of

the construction system, therefore they look at the production processes obtained from the scheduling of building works as dynamic cost-generating elements that change resources into outcomes. As a result, building budgets and schedules may be linked together thereafter. These models were made to aid in the estimation process by making tacit knowledge of the building's processes plain to those who acted on the plans [1,9]. Estimating construction costs is both an art and a science. The contractor must be able to comprehend and conceptualize a facility project and design the strategy for constructing the facility to be an accurate estimator. The finest estimators are also skilled at analyzing past building costs and predicting the factors that will increase or decrease future costs [2]. Building estimated costs, or "estimates," are often formed throughout a project. To determine whether a project is economically feasible, the owner may create extremely preliminary feasibility estimates. To ensure the project is designed to the owner's budget, a designer or construction manager may build a sequence of progressively detailed approximations during the design process. A general servicer or trade contractor will decide to generate estimates to limit their bid or low values for a project. And many estimates might be developed industrially to assess the impact of different design decisions or create a cost estimate for a design modification throughout the construction process. Cost projections for construction projects are overly detailed and have varying degrees of accuracy. The RS Means levels of detail can be used as a guide when developing part-level definitions [3].

4. Averaged Square Base Estimate

These approximations are based on average statistical norms for a building's cost per square foot or unit cost. Although this correctness can vary, they are expected to be accurate within +/- 20%. This estimation can be made with limited information, such as the number of carriages for a parking garage as well as an approximation of the square footage for an office building. This calculation can be made during the planning stage and shouldn't take more than ten minutes [4].

5. Demonstrated Square Foot Estimate

These estimations use existing model structures to construct a structure representative of the upcoming building. Although this method is projected to be accurate to within +/- 15%, the accuracy can vary greatly depending on how strong the assumptions are. The Modeled Square Foot approximation method requires the contractor to have a general notion of the structure's footprint, be familiar with the structural system, and be aware of the facade plan. This estimating method typically takes an hour to complete and can be utilized during the Schematic Design stage [10].

6. Assemblies Estimate

A project's meetings are identified, valued, and quantified to create an assembly estimate. They are anticipated to be within 10% of the actual value. The contractor must be able to recognize a system-equal design and perform quantity departures for multiple schemes to estimate a project. Usually, this can happen throughout the project development period. He typically needs one day to create this kind of approximation, spending most of that time conducting quantity takeoffs (quantifying the amount of each item) [6].

7. Unit Value Estimate

In a component price estimate, every item restricted to the project is defined, and the materials are priced after the precise construction techniques that will be utilized to a specified concept. Depending on the intricacy of the project, this method can be accurate to within +/- 5% of the cost. This approximation typically occurs close to or after the construction documents phase since it requires a relatively detailed design. A thorough estimate of every item in a structure can take up to three weeks, with a lot of effort spent on execution quantity takeoffs [6].

Based on a review of the relevant literature, a thorough list of 27-factor indicators was compiled, and a questionnaire was constructed to solicit feedback from Iraqi construction project managers. The factors are outlined in Table 1.

Table 1 The major factors regading the cost estimation in construction project

Main Factor	Sub-Factor	Coding	Main Factor	Sub-Factor	Coding
Labor-related factors (F1)	Frequent exposure of workers to accidents	SF1	Equipment related factors (F4)	Lack of equipment on site	SF24
	Poor use of resources	SF2		Delay in the delivery of equipment	SF25
	Poor use of technology	SF3		Poor equipment productivity	SF26
	Poor understanding of working methods	SF4		Poor ability to operate equipment	SF27
	Low labor productivity	SF5		Frequent equipment malfunctions	SF28
	unskilled labour	SF6		Poor maintenance of equipment	SF29
	Skilled labor shortage	SF7			F5
Material related factors (F2)		F2	Management related factors (F5)	Poor construction planning	SF30
	Poor availability of materials in the market	SF8		weakness in decision making	SF31
	Delayed delivery of materials to the site	SF9		Low management skills	SF32
	weakness in Material quality	SF10		Too much owner interference	SF33
	uprise material prices	SF11		Additional business change of owner	SF34
	poor Material management	SF12		delay in payment	SF35
	Poor storage of materials	SF13		bureaucracy	SF36
Contractor related factors (F3)		F3			
	Poor contractor experience	SF14			
	Contractor productivity is not acceptable	SF15			
	Slow to make a decision	SF16			
	Poor management on site	SF17			
	Contractor's financial problems	SF18			
	Delays/mistakes due to subcontractors	SF19			
	Poor communication and coordination	SF20			

2 Methodology of present work

The primary objective of the research is to discover which components of construction projects are the most crucial to address. A skilled group of specialists must perform the rating. The Delphi technique offers the researcher a flexible and adjustable data collection and evaluation instrument. Some of the reasons why the Delphi approach is utilized are as follows [11,12]: The word "method to evaluation" refers to comprehending each focused component in depth. Input is required to find the most cost-effective approaches for factor management and to evaluate the variables that must be managed. It takes both the causes and effects of the factors into consideration. Combining outcomes and probability while analyzing and investigating causes is a usual practice. Factor assessments could be qualitative, quantitative, or semi-quantitative [13]. When there are disparities in the data quality or the data sources, quantitative analysis is not always the best solution. Under these conditions, it is possible to do a thorough qualitative analysis with the same level of specificity. Regardless of the approach employed, the documentation for the study should include a description of the data quality and the data sources used in the investigation. In addition, you must include a description and explanation of the system and the problem definition, as well as identified factor sources and factors, initiation events, etc. According to the findings of this study, the significance of cost-estimating challenges is evaluated in a practical and effective manner [14,15]. Using the Firefly approach and enhancing it with a scanning methodology, elewe et al. [16,17] built a new set of techniques for managing such complicated research problems, which were considered cutting-edge at the time. Using the MC-GPSO methodology, Talib et al. [18,19] and bin Hasnan et al. [20,21]created a method for tackling huge problems. [22] and [23] individually. In [24], Majeed et al. made an assimilated ANN for defect pattern recognition, which was later reported by [25,26]. A common principle in factor management asserts that the party with the most relevant abilities and qualifications will execute the most effective factor management. As a result, specific responsibilities might be outsourced to a single organization, ensuring that the enterprise is safeguarded or that the repercussions of the relevant conditions are avoided [27]. In the first stage of this work, which consisted of identifying the study area, the cost estimation criteria were determined using the Delphi method based on pertinent literature and expert opinion. In the second stage, the researcher determined the Importance Regression Ensemble Method of factors for each region. In the third step, the K-Nearest Neighbor Method was developed utilizing MATLAB software, which examines the given data to identify and evaluate factors and to establish the factor rating. On the basis of the Importance Regression Ensemble Method and K-Nearest Neighbor Method findings, the influencing variables of building projects were identified and tested.

3 Result and discussion

3.1 Importance regression ensemble results

Importance Regression Ensemble analysis ranks indicators based on participant replies that determine the majority of significant criteria (Figure 1 - Figure 5). The relative relevance of the criterion was determined using a relative index analysis. Following are tables containing the relative index study's ranking results for each region. As a result of these rankings, twenty hazards were identified as having a high level of importance in assessing the implications of cost estimation on building projects.

The Importance Regression Ensemble was constructed to uncover each challenge's of the cost estimation of the construction project. These factors were ranked using the Importance Regression Ensemble values that were produced.

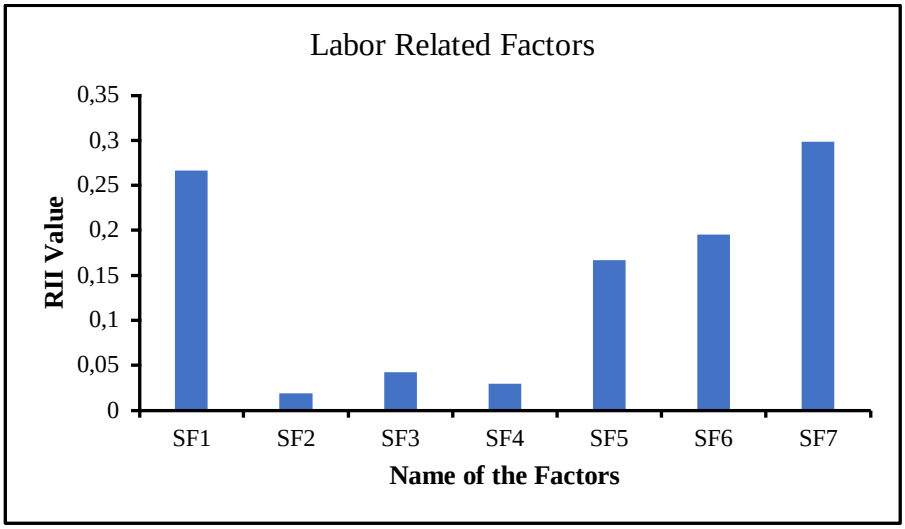

Figure 1 Importance Regression Ensemble of labor related factors respond scoring

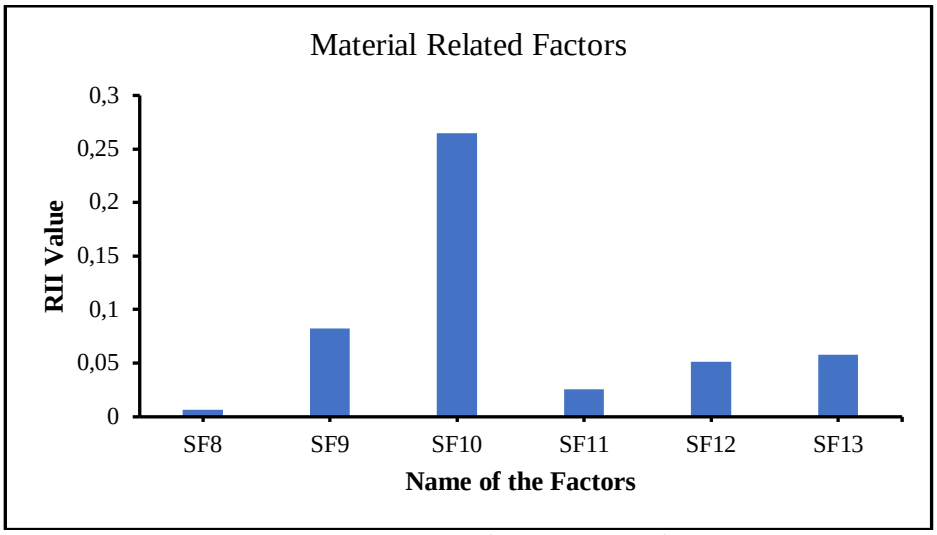

Figure 2 Importance Regression Ensemble of material related factors respond scoring

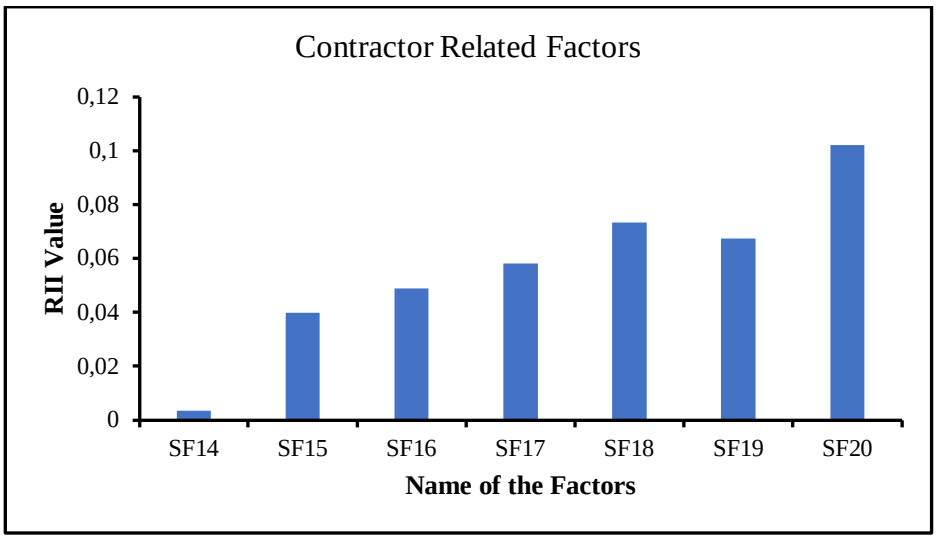

Figure 3 Importance Regression Ensemble of material related factors respond scoring

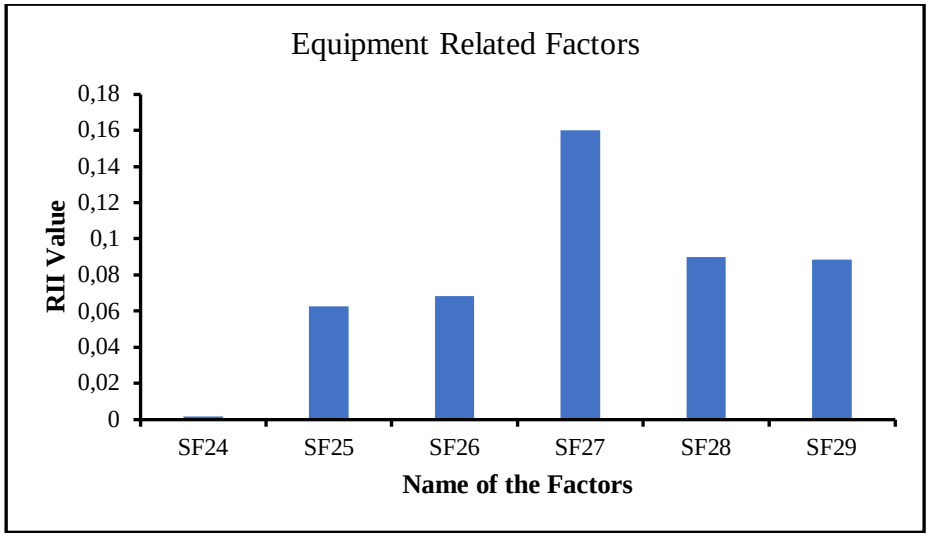

Figure 4 Importance Regression Ensemble of equipment related factors respond scoring

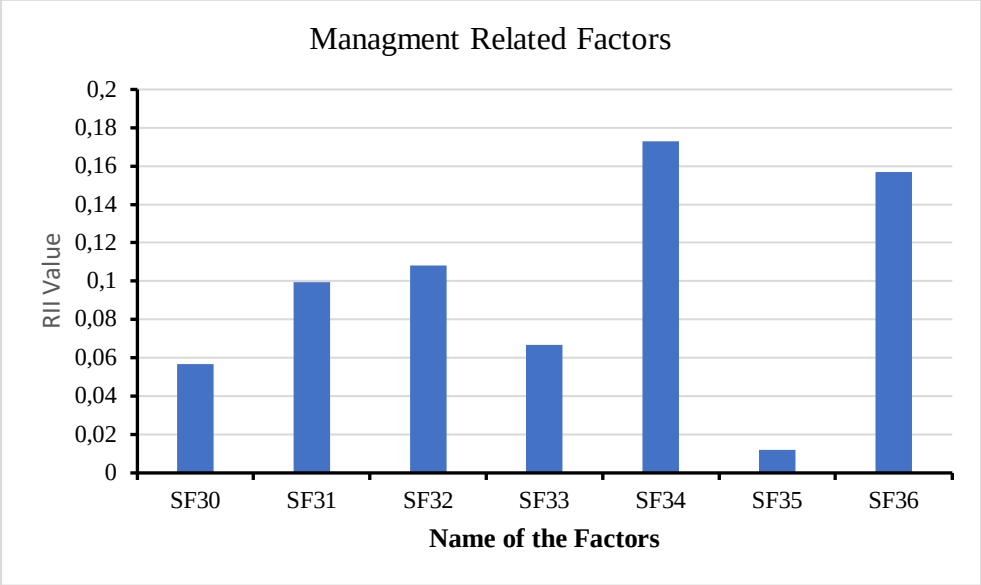

Figure 5 Importance Regression Ensemble of management related factors respond scoring

3.2 K-Nearest Neighbour Method Results

The K-Nearest Neighbour Method analysis results are reported in the following sections (Table 2). The K-Nearest Neighbour Method analysis results for each region are presented in the tables shown in the following sections. Based on these ranking results, it was found that the selected factors had considerable degrees of importance in the factor evaluation of building projects based on the effects of cost estimation. The K-Nearest Neighbour Method was applied for each building cost estimation component to identify factor components. These criteria were ranked based on the K-Nearest Neighbour Method's outcomes. It presents a significant cost estimation risk. In addition, the parent construction trash disposal is a major source of cost estimation complications. According to the research, these components were identified as an intriguing cost estimation contributing factor. Comparing the results that the top higher ranks, as shown in the table, are much higher. According to the experts, the results indicate that the Method has a high degree of reliability.

Table 2 K-Nearest Neighbor Method's outcomes

Project	Actual cost	Estimated cost	Error
building size 200m3	46393	47872	3%
building size 300m4	71373	72783	2%
building size 400m5	119336	103021	14%
building size 500m3	84899	84920	0%
building size 600m4	130613	130846	0%
building size 700m5	218386	220662	1%
building size 800m3	155365	162658	5%
building size 900m4	239023	222370	7%
building size 1000m3	399646	389708	2%

4 Conclusion

This study aims to establish a unique way of estimating project cost concerns in Iraq by creating a model that can aid parties involved in construction projects to recognize obstacles and factors in advance. These strategies and procedures were employed to achieve this objective. The current study created a hybrid strategy for identifying precise cost estimations in Iraqi construction projects. The study identifies five primary effective elements with thirty-six sub-factors in the Iraqi market. It evaluates them using prior studies, questionnaires, and a survey of twenty building projects to create a database of matrix factors for construction projects. This study aimed to determine the cost components based on relevant research and expert opinions. In the second phase, the researcher ranked the factors using the Importance Regression Ensemble Method and then utilized the K-Nearest Neighbor Method to determine the effect of the near-effective factors on the cost.

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Impact of dividend policy on stock prices
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Impact of dividend policy on stock prices

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Keywords: stock price, dividend policy, capital structure, profitability, Universitas Pekalongan.
Abstract: This study aims to test and analyze the research model by using dividend policy as an intervening variable on the effect of firm value and capital structure on firm value. Other variables influencing the stock price are investment opportunity set, trading volume activity, and profitability. The objects of this research are companies included in the LQ45 index on the Indonesia Stock Exchange during the period 2012 - 2021. The analytical tool we use is path analysis to test the effect of exogenous variables on endogenous variables, including testing direct and indirect effects. The results of testing 177 samples over a period of 10 years resulted in the finding that the dividend policy with the DPR (Dividend Payout Ratio) indicator was unable to mediate funding policy and firm value in increasing stock prices. Another study found that factors that increase SP (stock prices) in a positive and significant direction of influence are ROE (Return On Equity), and DPR (Dividend Payout Ratio), while other variables such as PER (Price Earning Ratio) and DER (Debt to Equity Ratio) do not significantly increase SP (Stock Prices) despite the positive direction of influence. While the factors that can reduce SP (Stock Prices) in our study are DAR (Debt to Assets Ratio) and TVA (Trading Volume Activity), and other factors that do not significantly reduce SP (Stock Prices) even though the direction of influence is negative are PBV (Price to Book Value) and ROA (Return on Assets).

1 Introduction

Spence [1] introduced signal theory by suggesting that a signal or signal provides a signal, and the sender (information owner) tries to provide relevant pieces of information that the receiver can utilize. The signal received will be interpreted according to the understanding of the recipient and result in a change in behaviour. Signalling theory explains how companies give signals to users of financial statements about what management must do to make efforts according to the wishes of the company owner. So it is hoped that the information provided is positive information about the company's performance which is better than other companies. In other words, companies can provide positive signals to be captured by potential investors in the form of investment in the company concerned.

According to Brigham and Houston [2], a signal is an action taken by a company to provide clues to investors about how management views the company's prospects. Information is an important issue issued by the company, and can affect investments made by external parties. Information, notes or descriptions, regarding past, present and future conditions for the continuity of the company's life and how the impacts that might arise.

The stock market has an important role in developing companies and plays a role in creating real economic growth. The performance of a stock can be influenced by different variables, both in terms of time and aspects, so that stock price movements sometimes cannot be predicted precisely because there are changes in surrounding variables including financial market variables, financial behaviour variables and others.

The stock market price is the price determined by the demand and supply of market participants for a share. Naturally, the stock price is a reflection of the company's performance, so if the stock price rises, this indicates good company performance. Increasing company performance from time to time can increase stock prices, and this is liked by investors [5-8]. This shows that there is a positive relationship between financial performance and stock price. The higher the financial performance the higher the share price, and vice versa.

The dynamics of a company's stock price can be seen from the closing price of its shares (closing price), which states the ups and downs of the stock price. Managers can maximize company value by setting good and correct policies to increase their company's share price. A company with a high share price reflects that the performance of the

company is good to be able tocreate a high share price, the company must first find out about the factors that can affect the share price. One of the factors that can affect stock prices is dividend policy. Dividend policy has the main aspect, namely determining the right distribution of company profits between being distributed as dividends or retained for company reinvestment.

Ruhani et al. [7] explained that there are many factors that affect stock prices such as earnings, dividends, bookkeeping value as internal factors,while external factors such as interest rates, government regulations, foreign exchange rates. Pearce et al. [8] The study explores the influence of economic variables such as money stock, real economic activity uses inflation indicators, namely changes in the consumer price index (CPI), producer price index (PPI), industrial production (IP), and the unemployment rate (RU), including the discount rate from the federal reserve. The results of the study suggest that monetary policy greatly affects stock prices, money stock has a negative effect on stock prices, the federal reserve's significant effect on stock prices, PPI has a significant impact when announced.The conclusion of the research conducted by Pearce et al. [8] is that the impact of these variables on stock prices can last long even though the news/announcement has passed. Our research has novelty compared to existing research, namely the placement of dividend policy proxied by dividend payout ratio as an intervening variable and dividend policy by dividing dividends with dividend payout ratio is still a tool for companies to attract investors, as evidenced during the 10-year period companies in corporated in LQ45 reached 96% paying dividends.

Black and Scholes [9] argue that the company pays dividends because it expects its share price to increase or there is a change. Changes in stock prices can be interpreted because the market reacts and expects the level of profit that can be obtained from the company. Dividends can help provide good information about the company's management to the capital market, so it can be said that dividends can help provide good information about the company's management [10]. So it can be said that dividends can be viewed as a signal to the company's prospects [11]. In the context of high information asymmetry, company management tends to pay dividends with a low ratio. Even though the company continues to distribute dividends, the dividend policy implemented by the company's management is not used as an instrument to reduce information asymmetry but is used to create a good corporate image [12].

1.1 Investment opportunity set and stock price

Earning Per Share (EPS) referring to signalling theory can provide investors with the right news signals [13]. Information about changes in stock prices and volumes contains information in providing useful evidence and can be used in decision making. The results of previous studies found that the PER has a positive and significant effect on stock price [13-16]. While Anwar and Rahmalia [18] found that although EPS has an effect on stock prices in a positive direction, it is not significant. Based on this, the first hypothesis is formulated as follows:

H1. Price earning ratio has a positive impact on the stock price.

1.2 Firm value and stock price

PBV represents the company's value will determine the information provided by the company to external parties how the company manages the company transparently. In signalling theory, the PBV value gives good news/positive signal to investors. The higher the PBV, the higher the investor's assessment of the company concerned relative to the funds invested. The higher the PBV, the higher the stock return so that it will increase the company's income and increase the company's ability to distribute dividends. The results of the study found that the PBV has a positive effect on stock prices and has a significant effect [14,15,18-20]. Based on this, the second hypothesis is formulated as follows:

H2. Price book value has a positive impact on the stock price.

1.3 Capital structure and stock price

One of the factors that affect stock prices is the company's capital structure, which is part of the financial structure. The concern is how the capital structure can be optimized to increase firm value. How then fluctuations in the capital structure can affect the company's policy on finance because there is always a trade-off between the benefits and costs of each funding policy taken by the company. Trade-off theory according to Myers [22] explain that company will go into debt up to a certain level of debt, where the tax savings (tax shields) from additional debt are equal to the cost of financial distress. The results found that the capital structure with an indicator of debt ratio or debt to asset ratio has a significant positive effect on stock prices [22-24]. While the capital structure using the DER indicator found the fact that DER is significantly positive to the stock price [26]. While the capital structure using the DER indicator found the fact that DER is significantly positive on stock prices, another study found that DER although positive but its effect is not significant [13,26]. While Novison et al. [28] found that DER has a significant negative effect on stock returns. Based on this, the third and fourth hypotheses are formulated as follows :
H3. Debt to asset ratio has a positive impact on stock price
H4. Debt to equity ratio has a positive impact on stock price

1.4 Profitability and stock price

Research that has been conducted finds that the level of profitability greatly affects the company's stock price (Net Profit Margin), this shows that profitability shows a positive signal for investors to make company stock purchase transactions [25,28-30]. More specifically, the

results of the study of profitability influence on stock prices using the ROE indicator found that ROE has a significant positive effect on stock prices [24,26], although there are also studies that find that although the effect of ROA is positive, it does not significantly affect stock prices [32]. The more extreme thing in another study found that ROA has a negative but insignificant effect on stock prices [30,32].

The ROE indicator is often used as a profitability variable, and previous studies show strong evidence that ROE is one of the determinants of stock prices. This is supported by the results of studies which state that ROE has a positive effect on stock prices [17,25,27,32,33]. While other studies found that ROE is positively insignificant [26,28]. The opposite is stated by Choiriya et al. [32] who found that ROE is significantly negative to stock prices. Based on this, the fifth and sixth hypotheses are formulated as follows:

H5. Return on assets ratio has a positive impact on stock price.
H6. Return equity ratio has a positive impact on stock price.

1.5 Trading volume activity and stock price

Trading volume activity (TVA) is a function of supply and demand and can be used as a sign of changes in market strength and weakness. TVA is an important indicator for investors, because an increase in TVA is an increase in buying and selling activity by investors in the capital market [35]. Empirically shows that TVA has a positive effect on stock prices [34,35]. Based on this, the seventh hypothesis is formulated as follows :
H7. Trading volume activity has a positive impact on stock price

1.6 Dividend policy and stock price

Suganda and Sabbat [37] explains the distribution based on signalling theory, that dividend payments explain the company's prospects for future profits. DPR is the ratio that shareholders receive from the company based on a certain percentage of the profit level, this explains that the company is able to share the results, so that it can increase investor demand in the stock market. So that the higher the share price, the desire of investors to own/buy shares will increase [38]. Research finds that dividend policy represented by the DPR has a significant positive effect on stock price [20,22,28]. While Qureshi [19] explains that the payout ratio has a negative and insignificant influence on share price. Based on this, the eighth hypothesis is formulated as follows:

H8. Dividend payout ratio has a positive impact on stock price.

1.7 Firm value and dividend policy

PBV illustrates the market's financial value to the management and organization of a going concern company. PBV informs investors that the company is well managed, the higher the PBV of a company indicates the higher the physical assets and the higher the value of the company by investors. Meanwhile, the DPR is the percentage of income that must be paid to shareholders as cash dividends, and the higher the DPR will benefit investors. The combination of PBV and DPR is expected to increase investor confidence to make transactions on company shares. The study found that PBV has a positive effect on DPR [39]**.** Based on this, the ninth hypothesis is formulated as follows:

H9. Price to book value has a positive impact on dividend payout ratio.

1.8 Capital structure and dividend policy

Capital structure is the balance between the amount of debt owned by the company and the amount of assets or the amount of equity capital. An increase in debt will affect the level of net income received by shareholders, this is because the company will finance the debt first then the remaining profits will be distributed as dividends. It can be said that the capital structure has a negative influence on the DPR [40]. However, capital structure has a positive and significant effect on dividend policy. This shows that the higher capital structure will increase the dividend policy value, conversely the lower capital structure value will decrease the dividend policy value [40,41], although funding policy can also have a positive but not significant effect on DPR [43]. Based on this, the tenth and eleventh hypotheses are formulated as follows:

H10. Debt to assets ratio has a positive impact on dividend payout ratio.
H11. Debt to equity ratio has a positive impact on dividend payout ratio.

2 Methodology

2.1 Data Collection and Sources

The type of data used in this study is in the form of secondary data. The source of data used comes from the financial statements of LQ45 the period 2012 to 2021. The data in this study is panel data that is the type of data that is a combination of cross-sectional data and time series data, and therefore according to Gujarati [44], the method of analysis is a combination of time series data analysis and cross-sectional data analysis. Path analysis is used to answer research questions, and the dividend policy is exsogenous variable one (1), and stock price is exogenous variable two (2).

2.2 Empirical Model and Variable Measurement

The research was focused on the empirical test of variables integration related to the stock price involving investment opportunity cost, firm value, capital structure, profitability, and trading volume activity, mediated by dividend policy. The model of empirical study is presented in Figure 1.

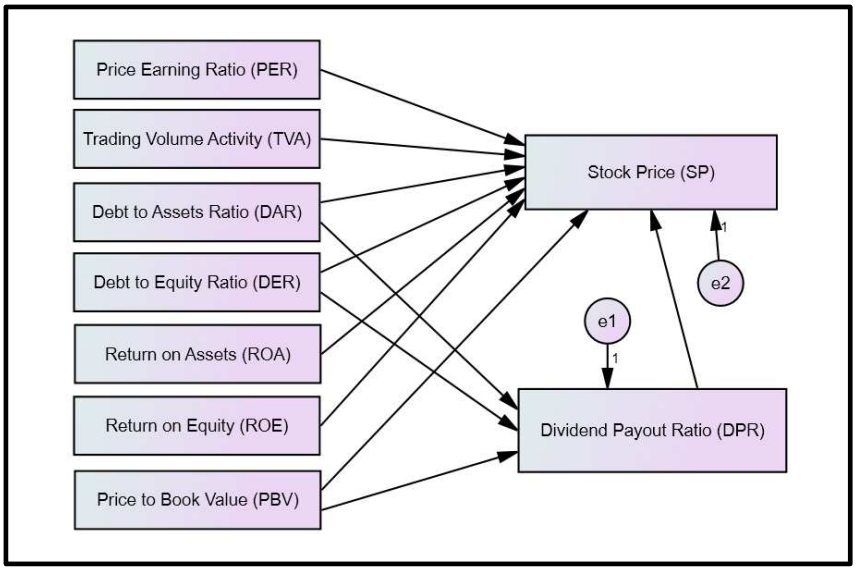

Figure 1 Empirical model research

Both sub-structures formed in figure 1 are the first, the sub-structure states the causal relationship of variables DPR, PER, PBV, DAR, DER, ROA, ROE,and TVA with SP variable; Second, the sub-structure shows the causal relationship between variables PBV, DAR, DER, with variable DPR. In other words, based on both sub-structures, there are 2 structural equations formed (1), (2):

$$SP = \beta_{1SP}DPR + \beta_{2SP}PER + \beta_{3SP}PBV + \beta_{4SP}DAR + \beta_{5SP}DER + \beta_{6SP}ROA + \beta_{7SP}ROE + \beta_{8SP}TVA + \varepsilon_1 \quad (1)$$

$$DPR = \beta_{1DPR}PBV + \beta_{2DPR}DAR + \beta_{3DPR}DER + \varepsilon_1 \quad (2)$$

Where :
SP = stock price, DPR = dividend payout ratio, PER = price earning ratio, PBV = price to book value, DAR = debt to assets ratio, DER = debt to equity ratio, ROA = return on assets, ROE = return on equity, TVA = trading volume activity.

Stock price used the measurement from closing price stock [1,2,22,29], price earning ratio often used as a proxy of investment opportunity set [1,14], firm value used proxy is price to book value [14,18], capital structure used proxy as debt to equity ratio and debt to assets ratio or debt ratio [37,44-46], profitability use proxy as return on assets and return on equity [17,25,27,31-33,44,48]. Trading volume activity use proxy from activity trading in capital market [1,34], and dividend policy use proxy as dividend payout ratio [1,22,45].

3 Result and discussion

3.1 Descriptive statistics

Descriptive statistics for variables are shown in Table 1. On average, the DPR data in Indonesia reaches 33.59% with the highest DPR value is 88.36% and the lowest is 2.91%. While for SP, the average is 5,836.89 with the highest SP is 25,000.00 and the lowest is 189.00.

Table 1 Descriptive statistics

Variable	N	Minimum	Maximum	Mean	Std. Deviation
Dividend payout ratio	177	2.91	88.36	33.5868	16.98932
Return on assets	177	0.64	18.54	6.6569	3.92184
Return on equity	177	1.07	27.12	13.5815	4.89760
Debt to assets ratio	177	0.13	0.88	0.5047	0.18996
Debt to equity ratio	177	0.15	7.31	1.6238	1.79391
Price earning ratio	177	5.12	40.01	16.7123	7.11637
Price to book value	177	0.36	6.01	2.2155	1.32704
Trading volume activity	177	4.43	30447.00	7147.6013	6489.43837
Stock price	177	189.00	25100.00	5836.8870	5457.80810

Source: SPSS Data Processing Results

Table 2 shows the Pearson correlation matrix and Vector Inflation Factor (VIF) among the variables. The results indicate that all variables are far from being correlated. The maximum correlation coefficient is 100.00% between ROE and DPR which indicates positive and significant correlation. While the lowest correlation is 1.50% between TVA and DER which indicates positive and no significant correlation.

Table 2 Pearson correlation matrix

Variable	Dividend payout ratio	Return on assets	Return on equity	Debt to assets ratio	Debt to equity ratio	Price earning ratio	Price to book value	Trading volume activity	Stock price
Dividend payout ratio	1								
Return on assets	0.268	1							
Return on equity	0.100	0.610	1						
Debt to assets ratio	-0.285	-0.751	0.020	1					
Debt to equity ratio	-0.158	-0.575	0.216	0.855	1				
Price earning ratio	0.248	0.231	0.030	-0.234	-0.200	1			
Price to book value	0.298	0.569	0.602	-0.208	-0.049	0.733	1		
Trading volume activity	-0.164	-0.191	-0.227	0.018	0.015	-0.074	-0.197	1	
Stock price	0.227	0.192	0.347	0.008	0.125	0.066	0.237	-0.477	1

Source: SPSS Data Processing Results

3.2 Empirical model assumption test results

Table 3 shows the multivariate CR value of 2.426 < 2.58, so it can be concluded that the data in this study is normally distributed. Thus the normality assumption has been met and the data used in this study is suitable for further estimation.

Table 3 Data Normality

Variable	Min	Max	Skew	C.R.	kurtosis	C.R.
Dividend payout ratio	2.910	88.360	0.065	0.351	-0.425	-1.153
Return on assets	0.640	18.540	0.703	3.816	-0.381	-1.033
Return on equity	1.070	27.120	0.237	1.290	-0.140	-0.381
Debt to assets ratio	0.130	0.880	0.259	1.406	-0.563	-1.530
Debt to equity ratio	0.150	7.310	1.913	10.389	2.440	6.626
Price earning ratio	5.120	40.010	0.766	4.163	0.102	0.276
Price to book value	0.360	6.010	1.040	5.647	0.358	0.972
Trading volume activity	4.430	30447.000	1.410	7.657	1.864	5.061
Stock price	189.000	25,100.000	1.349	7.328	1.559	4.233
Multivariate					5.131	2.426

Source: AMOS Data Processing Results

The Mahalanobis distance is based on the chi-square value in the distribution table of the X^2 distribution table at a degree of freedom of 9 variables at a level of p < 0.001, namely X^2 (9;0,001) = 27.87716. SEM results show observations farthest from the centroid (Mahalanobis distance), namely the most distant data is 19.348 and the closest is 7.383, so that this research data is not detected multivariate outliers. Meanwhile, the results of the determinant of sample covariance matrix test show that the determinant of sample value is greater than 1, so there is no multicollinearity and singularity.

3.3 Empirical model feasibility test results

The empirical model feasibility results presented in table 4 show that all criteria in the feasibility test are met, so the data can be said to be free from*outliers.*

Table 4 Summary of Evaluation Results Goodness of Fit EmpiricalResearch Model

Goodness Of Fit Index	*Cut-Off Value*	Model Result	Description
Absolute Measures			
X^2 - Chi-Square	$< x^2, df, \propto$	6.717	value X^2 with df 3 probability 0.05 as 7.81473. Chi-Square value 6.717 is smaller
Probability	≥ 0.05	0.152	Very good
Minimum Sample Discrepancy Function Divided with Degree of Freedom (CMIN/DF)	≤ 2.00	1.679	Very good
Root Mean Square Error of Approximation (RMSEA)	≤ 0.08	0.062	Very good
Goodness of fit Index (GFI)	≥ 0.90	0.995	Very good
Incremental Fit Measures			
Adjusted Goodness of Fit Index (AGFI)	≥ 0.90	0.907	Very good
Tucker Lewis Index (TLI)	≥ 0.95	0.982	Very good
Comparative Fit Index (CFI)	≥ 0.95	0.999	Very good
Normed Fit Index Fit Index (NFI)	≥ 0.90	0.995	Very good

Source: Data processed from the results of SEM

3.4 Path analysis test result

Initially, we estimate the path analysis using AMOS. The results are reported in Table 5.

Table 5 Output path analysis

Variable			Estimate	S.E.	C.R.	P	Label
Dividend payout ratio	<---	Debt to assets ratio	-0.419	12.625	-2.970	0.003	par_16
Dividend payout ratio	<---	Debt to equity ratio	0.211	1.309	1.528	0.127	par_22
Dividend payout ratio	<---	Price to book value	0.221	0.939	3.020	0.003	par_29
Stock price	<---	Trading volume activity	-0.430	0.055	-6.589	0.000	par_1
Stock price	<---	Debt to assets ratio	-0.472	6,860.548	-1.969	0.049	par_2
Stock price	<---	Debt to equity ratio	0.135	486.860	0.841	0.400	par_3
Stock price	<---	Price earning ratio	0.135	107.189	0.959	0.338	par_14
Stock price	<---	Return on assets	-0.530	514.506	-1.427	0.154	par_15
Stock price	<---	Dividend payout ratio	0.136	21.840	1.994	0.046	par_30
Stock price	<---	Price to book value	-0.156	749.562	-0.852	0.394	par_31
Stock price	<---	Debt to equity ratio	0.631	283.991	2.463	0.014	par_32

Source: Data processed from the results of SEM

The equation obtained from table 5 with endogenous variables stock price (SP) and Dividend Payout Ratio (DPR) is:

$$SP = 0.136DPR + 0.135PER - 0.156PBV - 0.472DAR + 0.135DER - 0.530ROA + 0.631ROE - 0.430TVA$$
$$P = 0.046(DPR) + 0.338(PER) + 0.394PBV + 0.049(DAR) + 0.400(DER) + 0.154(ROA) + 0.014(ROE) + 0.000(TVA)$$
$$CR = 1.994(DPR) + 0.959(PER) - 0.852PBV - 1.969(DAR) + 0.841(DER) - 1.427(ROA) + 2.463(ROE) - 6589(TVA)$$

$$DPR = 0.221PBV - 0.419DAR + 0.211DER$$
$$P = 0.003PBV + 0.003DAR + 0.127DER$$
$$CR = 3.020PBV - 2.970DAR + 1.528DER$$

Where:
SP = stock price, DPR = dividend payout ratio, PER = price earnings ratio, PBV = price to book value, DAR = debt to assets ratio, DER = debt to equity ratio, ROA = return on assets, ROE = return on equity, TVA = trading volume activity

3.4.1 Test results of investment opportunity set and stock price

The influence of PER to SP is positive but no significant influence. The PER in this study was not able to significantly increase stock prices. The signal given by the increase in PER is not responded meaningfully by investors to make stock purchase transactions, so that although the direction of the effect is positive, it is not significant. This result supports the one done by Anwar and Rahmalia [18] explains that the relationship between PER and SP is a positive relationship. However, it does not support the finding that the PER ratio has a positive and significant effect on SP [13-15,47].

3.4.2 Firm value and sock price test results

The test results found that the direction of the influence of PBV is known to be negative on stock price but not significant. This can be due to the existence of asymmetric information so that the adequacy of information greatly affects buying interest in traded stocks, allegedly the shares in the sample in this study do not provide enough information about the company, thus providing a negative influence. This study is not in line with research conducted by Andamari et al. [16], Sari [15] Qureshi [19], Digdowiseiso and Fadillah [20], and Bustani et al. [21].

3.4.3 Test results of capital structure and stock price

There are different findings on the capital structure indicators in this study, the capital structure with the DAR indicator found that the direction of the effect of DAR on SP is negative and significant. Increased financing using debt is considered by investors as the right policy according to the trade-off theory [22]. The results of this study do not support the research finding that the debt ratio or debt to asset ratio has a significant positive effect on stock prices [22-24].

Another finding of the capital structure with the DER indicator is that the direction of the DER effect on stock prices is positive but not significant. A high DER exceeds the capital provided, considered by investors that the company is able to manage debt sources, and is able to generate profits exceeding the cost of capital so that the direction of influence is positive. However, it does not have a larger portion so that although it is positive, it is not significant. This result is in accordance with Safitri et al. [14], and Indrajaya [27], However, it does not support the study Tarsono [26].

3.4.4 Profitability and stock price test results

The profitability variable using the ROA indicator is known to have a negative direction of influence on stock

prices but is not significant. The signals provided by ROA are insufficient to lift stock prices, and even tend to be captured by investors negatively. The comparison of profit earned with the amount of company assets in this study is not a matter of consideration for investors in buying shares, there are factors that are more important to investors, which are the amount of profit compared to the capital owned. This supports the findings of Hadi & Nurhayati [33], and Hidayat et al. [31], but not in accordance with the findings of Choiriya et al. [32]. Profitability with ROE measurement tool found a positive direction of influence on stock prices and significant. So, profitability is considered to provide a positive signal to stock purchase transactions [25,28-30]. The positive signal is captured by making transactions that increase the share price significantly. This result supports the findings of Mudzakar et al. [25] and Indrajaya [27], but does not support the study of Choiriya et al. [32].

3.4.5 Test results of trading volume activity and stock price

The findings of this study indicate that the direction of TVA on stock prices is negative and significant. An increase in stock trading transactions that shows strength and supply is not responded positively by investors, it actually reduces the stock price. So, it can be said that the stock price factor is determined by other factors outside of trading transactions, namely macro economic fundamental factors such as interest rates, inflation rates, exchange rate fluctuations, government policies, panic factors, market manipulation factors, and also other internal company factors such as corporate actions and projections of future company performance. This finding does not support the study of Fajri et al. [35], and Mutakif and Nurwulandari [36].

3.4.6 Dividend policy and stock price test results

The results found that DPR has a significant positive effect on stock prices. DPR provides information about the company's prospects in the future so that it is captured positively by investors in the form of increased demand for the company's shares, which in turn can increase the price. This result supports the findings of Bustani et al. [21], Hussainey et al. [23], and Hunjra et al. [29], but is not in accordance with the study of Qureshi [19].

3.4.7 Firm value and dividend policy test results

The test results found that firm value with the PBV indicator has a positive effect on dividend policy and is significant. The value of the company shows high investor confidence in the company while increasing investors' expectations of obtaining a share of the profits (dividends) from the profits earned by the company. This study supports research conducted by Rahayu et al. [39].

3.4.8 Test results of capital structure and dividend policy

The test results on capital structure with the DAR indicator are known to have a negative and significant effect on DPR. Financing assets using debt isconsidered by investors to have a high risk based on trade off theory, thus affecting investors in carrying out trading transactions and reducing stock prices. This result is in accordance with research Suarjana and Warmana [40] which found that capital structure has a positive effect on dividend policy. While the capital structure with DER indicator affects the DPR although positive but not significant. The view that DER has a positive effect focuses more on the existence of debt will motivate the company to increase profits above the tolerable risk. Even so, it still does not significantly affect stock trading transactions to increase stock prices. These results support research conducted by Simanjutak and Kiswanto [43], but not in accordance with the findings of Dewi et al. [41], and Ifada et al. [42].

4 Discussion

4.1 Firm value test results on stock prices with dividend policy as a mediating variable

The coefficient value of the direct effect of PBV on the stock price variable is -0.155. Meanwhile, the indirect effect of PBV variable, through the mediation of DPR variable, on stock price variable is 0.0263. Thus, the effect of PBV on Stock price is mediated by DPR, however, the Sobel test results show that it is not significant (Sobel test 0.001427 < t table 1.65397). These results indicate that the company value in this study is not able to increase the stock price even though the company has issued a dividend policy to its investors.

4.2 The test results of capital structure on stock prices with dividend policy ratio as a mediating variable

The coefficient value of the direct effect of DAR on the stock price variable is -0.469. Meanwhile, the indirect effect of DAR variable, through the mediation of DPR variable, on stock price variable is -0.0585. Thus, the effect of DAR on Stock price is mediated by DPR, however, the Sobel test results show that it is not significant (Sobel test 0.000207 < t table 1.65397). These results prove that although dividend policy can be a tool to increase stock prices eventhough companies take debt, the effect is not significant, in the sense that the level of prudence of management taking funding policies must still be prioritized by considering the risk aspects of the funding policy itself.

The coefficient value of the direct effect of DER on the stock price variable is 0.134. Meanwhile, the indirect effect of the DER variable, through the mediation of the DPR variable, on the stock price variable is 0.0302. Thus,the effect of DER on Stock price is not mediated by DPR. With these findings, it can be explained that a larger portion of

funding from debt will not be able to increase stock prices even though the company pays dividends. The financial difficulties that overshadow funding policies remain an indicator that investors care about for companies that owe more than the amount of capital they have.

5 Conclusion and implications

The results of our study conclude that dividend policy with the DPR indicator is not able to mediate funding policy and firm value in increasing stock prices. Dividend policy in this study has not attracted investors to buy shares and increase transactions, although as an independent variable itself DPR has a significant effect on stock prices. It is also known that the factors that can increase stock prices in a positive and significant direction of influenceare ROE, and DPR, while other variables such as PER and DER do not significantly increase stock prices even though the direction of influence is positive. Factors that can reduce stock prices in our study are DAR and TVA, and other factors that do not significantly reduce stock prices even though the direction of influence is negative are PBV and ROA.

The dividend policy in our study does not support the signalling theory proposed by Spence [1]. The company's expectation by paying dividends is not able to increase stock prices, if the company takes a funding policy by increasing debt. Our findings support the study conducted by Miller and Modigliani [50] dividend Irrelevance Theory, so even though the company pays dividends in fact it is not able to have a positive impact on investors. Investors still see the level of risk if the company takes debt, then still pays dividends. Dividends are considered not to increase investor welfare, if there are investment opportunities. Our study also reinforces the Trade-off theory expressed by the authors Myers [22] which explains that the company will go into debt up to a certain level of debt, where the tax shields from additional debt are equal to the cost of financial distress. Trade-off theory in determining the optimal capital structure includes several factors including taxes, agency costs (agency theory) and financial distress but still maintains the assumptions of market efficiency and symmetric information as the balance and benefits of using debt. The optimal interest rate is reached when the tax shield reaches the maximum amount against the costs of financial distress.

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A systematic literature mapping of current academic research linking warehouse management systems to the third-party logistics context

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Keywords: WMS, warehouse management systems, third-party logistics operator, systematic literature review.
Abstract: Academic research on third-party logistics operators selecting warehouse management systems is scarce at best, based on found 86 area-specific studies written in English. Only 17 studies had mentions of 3PL and WMS but did not directly reference 3PL using WMS. Eighty-six studies covering four main categories contributed to understanding ongoing research in WMS characteristics and the 3PL context. One category is warehouse characteristics relevant to WMS, and the others concern the warehouse management system as its taxonomy, functions, features, and deployment considerations. Within these four categories, 17 subtopic areas were identified. WMS deployment considerations had the highest number of subtopics (ten), being the most focused area for WMS selection considerations for the system's successful implementation and operation usage. WMS functions and features category contained only a subtopic, indicating a need for additional research on operational functions in management systems and 3PL operations context. Award-winning 3PL validated our findings, utilizing their extensive industry experience. Based on the 3PLs validation review, fast-developing and technology areas, such as digitalization and the newest warehouse management technologies, were the only areas missing from the academic literature. Research is carried out to map the missing specific digitalization, technology-based research, development, innovation possibilities, and WMS sustainability-related knowledge gaps. By addressing the knowledge gap in existing literature, the study significantly contributes to understanding WMS utilization in the 3PL context, providing new insights into WMS characteristics overview, advancing research in 3PL logistics selecting WMS, and defining future research venues of WMS aspects.

1 Introduction

The increasing demand for faster and more efficient supply chain operations has forced companies to ensure excellence in the supply and logistics-related business operations by adhering to the supply chain (SC) paradigm to be as strong as its weakest link [1]. Since the 1950s [2], as a general practice, companies have hired a third party to perform some of their non-core business activities [3,4] to be able to focus on their core business functions and outsource non-essential tasks [5,6]. Thus, a company can move from a make to a buy [7], employing value creation models offered by an outsourced company [8]. The top four reasons for outsourcing are decreasing costs, accessing unavailable in-house information technology (IT) resources, enhancing business processes, and freeing internal resources and time to focus on customers [9]. Furthermore, 3PLs have recently transformed from "just asset providers" to strategic SC decision-making partners [10,11]. What makes the selection of the right 3PL one of the strategic decisions for leading companies/vendors and main contractors in SCs [12] is the need for proper trust-building models [13].

The global third-party logistics providers (3PL) market is projected to reach $1.3 trillion by 2028, with a growing number of companies recognizing the benefits of outsourcing logistics and supply chain management activities [14]. Most companies confirm that warehousing and transportation are one of the most commonly outsourced activities [15,16]. As [17] has shown, warehousing is currently among the most outsourced service. Interestingly, a warehouse is also widely recognized as a crucial node in the total performance of the whole SC [18-21].

Considering the high importance of warehousing to SC performance and the vast competitiveness of outsourcing markets, 3PLs need to maintain the best knowledge [22] and understand their role in SC [23]. Likewise, 3PLs should comply with their customer's current and future demands and concerns and keep up with fast technology development cycles as technology advancements impact SC performance [24]. In this context, 3PLs explore novel, new, and more sustainable services for their customers and search for new systems and technology solutions to enhance outsourcing [25]. Advanced data information systems and ICT systems play center stage in sharing crucial operations information across all SC actors [26-31]. Digital technologies and information systems integration significantly transform and advance information value for SC operations [32-34]. Over the past decade, research has constantly reported a positive correlation between the implementation of advanced technologies in warehousing and a company's bottom-line growth as reduced costs and

lead times, previously unavailable information access, and operations transparency [35-39]. The main trends in previous years' literature are related to the concept of Logistic 4.0 in warehousing development, such as robotization, simulation and optimization, radio-frequency identification (RFID), big data and warehouse data, automated guided vehicles (AGV), Internet of Things (IoT), and multi-agent systems [36]. [40] demonstrate the effectiveness of using simulation techniques to identify bottlenecks and solve complex problems in the operational environment. In the paradigm of Logistics 4.0, a warehouse management system (WMS from now on) is one of the innovative technologies to transform warehouse operations significantly [35] and impact SC operations [39].

WMS is among the four technologies to manage SC (such as barcoding, just-in-time, and material requirements planning) to implement in warehouses [41]. WMS is a software-based management system supporting warehouse operations recording [42] and managing all warehouse resources, such as inventory, storage space, personnel, and equipment [43]. A WMS aims to enhance and achieve efficiency in all warehousing activities [20]. The primary warehouse operations encompass receiving, storage, order picking, and shipping [21,44,45]. Nowadays, a WMS is among the trustworthy SC technologies for companies to enhance business performance to enhance companies' business performance [43]. For example, in the shipping industry, a WMS is frequently demanded technology by shippers from 3PLs, to whom they outsource logistics activities [46]. In food SCs, the top 3PL cold storage providers utilize WMSs heavily, too [43]. Reviewing best practices for 3PLs, a WMS is accounted as a critical technical component to make SC functions more transparent [39] Gupta et al. (2019). For 3PLs, WMSs increase management abilities and operational excellence as a part of advancements in the field of information systems. The goals of this study are to 1) map the current topic-specific literature focus area publications, 2) investigate topic-related research focus categories, and 3) add specific understanding related to current research gaps. To achieve these goals, the authors identified three main research questions (RQs):

RQ1: What are the WMS characteristics discussed in the literature relevant for 3PL warehousing activities involved in selecting WMS activities?

RQ2: What is the current focus of 3PL logistics selecting WMS?

RQ3: Are any relevant WMS aspects that need to be added to academic research on 3PL warehousing operators selecting WMSs?

The current study provides a valuable contribution to the literature on the topic of WMS selection and implementation by 3PLs. By synthesizing existing WMS-related literature, this research provides a comprehensive overview of the critical parameters that 3PL providers should consider selecting a WMS. Moreover, this study will identify potential avenues for future research to advance the understanding of WMS characteristics further.

2 Methodology

2.1 Research design

A systematic literature review (SLR) was used as a research methodology to reduce biases from authors' subjectivity [47,48]. Additionally, the nature of SLR should make it easier for other researchers to continue this work and replicate the results [49]. SLR is a well-known research method allowing transparent and reproducible literature analysis with predefined process steps [50], helping to identify, evaluate, and interpret all available research relevant to a particular research question, topic area, or phenomenon of interest [51]. Moreover, SLR is also considered at the top of the hierarchy of research evidence [52-54], providing academic evidence for the selected study field and focus area, with a rigorous process of theoretical synthesis of already published evidence in literature materials on the topic [51]. SLR lies at the heart of pragmatic management research" and can offer advancement for both the academic and practitioner communities [55]. The SLR approach and methodology applied in this research follow the PRISMA 2009 model (Preferred Reporting items for systematic reviews and meta-analyses) that offers a way to improve the quality of reporting systematic reviews [56]. A systematic mapping process [57] was selected to add depth to SLR findings based on SLR. In this extended analysis, we seek to demonstrate the distinctive warehouse logistics operating characteristics and what a 3PL should consider selecting WMS and system features. The mapping continued with a comprehensive analysis of area-specific publications in SLR to pinpoint specific research gaps and well-covered knowledge areas [58].

2.2 Research data collection

Figure 1 illustrates Prisma 2009 methods flow diagram implementation for the SLR applied in this study. In this research, we used the academic scientific library research portal tool, with access to nearly 100 databases (such as ABI/INFORM, Scopus, Web of Science, EBSCO, Emerald, and ProQuest, among others), to collect the research articles from online databases and extract academic literature. Any time frames did not limit the literature collection. The final round of data collection was performed on the 15th of July, 2021). The literature was collected with four keyword combination sets to maximize efficiency and widen the data collection phase. According to systematic mapping guidance [57], searching keywords were selected in such a way to address the RQs and find answers. Consequently, the keywords were defined to provide sufficient research material for the follow-up analysis. For comprehensiveness of keyword selection, in addition to academic knowledge, empirical experts from the context of the 3PL operations (including, but not limited to, the logistics operations company CEOs,

members of the board, key account managers, and operations team development members) were also interviewed to reveal most current terminology in use in this study area. These experts contributed to the keyword definition. In addition to the academics, the authors consulted on the research keyword definition phase. Having collected academics' and 3PL operators' opinions and additions to the keywords list, we continued interviewing WMS software solution providers for possible additions to cover all views on WMS and 3PL expertise-related matters.

Defining the possible keywords to be utilized in the academic literature collection phase, we found that using just the abbreviation "wms" alone, without its complete form, tended to produce a massive number of non-related publications due to its use in multiple research fields with numerous meanings. To overcome the overload utilization of "wms," we decided to use this three-letter abbreviation "wms" with its long-form "warehouse management system" with the Boolean operator AND. However, parentheses used together with "warehouse management system" significantly limited results leaving only a small sample of studies for further analysis. To address this issue, a complete spelling of "warehouse management system" was utilized instead of using parentheses to establish a connection between warehouse management and other systems within the warehouse.

To solve the issue, a complete word form of warehouse management system without parenthesis was used to include a connection to warehouse management and other systems in a warehouse. To cover the academic research on the 3PL operations, synonymous and interchangeable terms keywords were utilized too, namely, "3PL, "logistic service operator," and "third-party logistics". Furthermore, the search terms "selection" and "characteristics" were selected as additional keywords to focus on literature devoted to 3PLs selecting WMSs.

After keyword searches, publications type and metadata-based automated filters were applied to concentrate mainly on peer-reviewed journals, which were available for online search tools and written in English. Then, in the screening phase, all found duplicates (352 studies) were removed by utilizing and double-checking with Excel Zotero tools. After that, we excluded 1,589 studies based on their titles and abstracts that did not contribute to 3PL's selection process of WMS, e.g., algorithms application in a warehouse, risk management, order-picking strategy, inventory positioning, or general SC views. After filtering out the non-contributing studies and publications, a full-text evaluation was continued with the 115 studies, which were accessed as potentially eligible for contributing to this research work. The full-text review of the potential 115 studies ended with 86 studies, contributing to our SLR studies analysis phase.

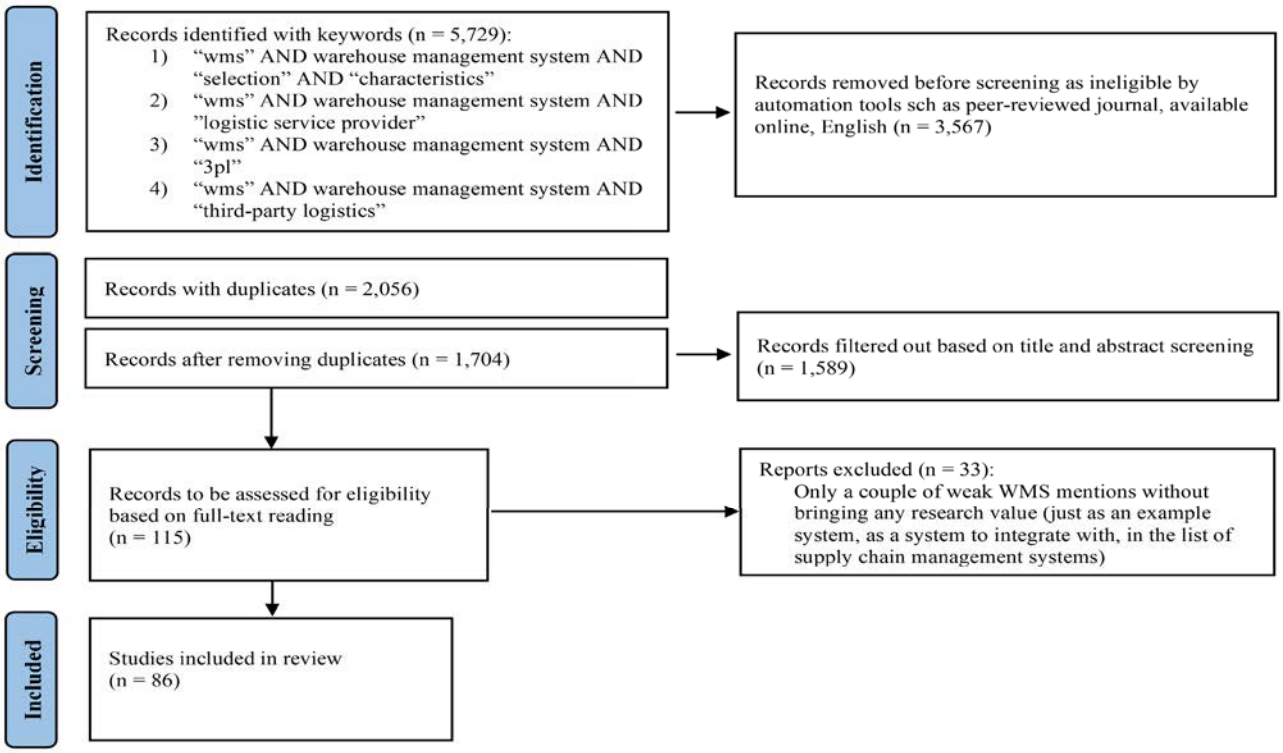

Figure 1 The utilized SLR process steps in the study, adapted from [54,56,59]

3 Literature review and analysis

The presentation of SLR analysis is started through a summary in Table 1 illustrating detailed specific areas of research contributions the found 86 sources.

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A systematic literature mapping of current academic research linking warehouse management systems to the third-party logistics context

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Table 1 Comprehensive SLR results in summary table format

YEAR	ID/REFERENCE	WAREHOUSE CHARACTERISTICS FOR WMS FUNCTIONALITY					WMS TAXONOMY		WMS FUNCTIONS AND FEATURES	WMS DEPLOYMENT CONSIDERATIONS									Number of aspects mentions (X) in topics in each study					
		Reference to 3PL operators and WMS	Warehouse type	Warehouse operational specifications (performance, processes, SKUs characteristics, order lines and etc.)	Warehouse physical parameters (size, layout and etc.)	Warehouse automation systems description	WMS definition	WMS types	WMS functions and features	WMS fitness to business, scalability & modularity	Integration with logistics automation & communication systems	Warehouse database integration	WMS user interface	WMS replacement	WMS implementation time	WMS costs aspects	WMS vendor support service	Quality verification	Vendor's reputation	Reference to 3PL operators and WMS	Warehouse characteristics for WMS functionality	WMS taxonomy	WMS functions and features	WMS deployment considerations	Overall study significance among five topics
1996	[113]						X				X				X	X				0	0	1	0	3	4
1997	[95]				X	X			X											0	2	0	1	0	3
	[96]					X	X		X						X	X			X	0	1	1	1	3	6
1998	[114]						X		X	X						X				0	0	1	1	2	4
	[140]															X	X		X	0	0	0	0	3	3
	[100]					X		X			X	X					X			0	1	1	0	3	5
1999	[108]					X														0	1	0	0	0	1
2000	[60]	X						X	X		X				X	X				1	0	1	1	3	6
	[103]						X			X										0	0	1	0	1	2
	[85]			X	X	X														0	3	0	0	0	3
2001	[119]								X											0	0	0	1	0	1
	[120]								X											0	0	0	1	0	1
2002	[132]									X	X			X						0	0	0	0	3	3
	[82]		X	X	X	X	X	X	X	X	X				X	X	X			0	4	2	1	5	12
	[67]	X						X		X		X								1	0	1	0	2	4
2003	[130]									X	X	X	X		X	X			X	0	0	0	0	7	7
2004	[61]	X																		1	0	0	0	0	1
	[62]	X																		1	0	0	0	0	1
	[91]			X		X			X		X									0	2	0	1	1	4
	[125]								X											0	0	0	1	0	1
	[99]	X						X			X		X							1	0	1	0	2	4
2005	[44]					X					X									0	1	0	0	1	2
2006	[133]										X									0	0	0	0	1	1
	[80]		X					X	X	X	X	X	X		X	X	X	X	X	0	1	1	1	9	12
	[92]			X			X			X										0	1	1	0	1	3
2007	[94]			X			X		X		X									0	1	1	1	1	4
	[81]		X				X									X				0	1	1	0	1	3
	[65]	X						X	X							X				1	0	1	1	1	4
	[86]			X		X	X	X	X	X	X	X	X	X	X	X	X		X	0	2	2	1	9	14
2009	[118]							X	X											0	0	1	1	0	2
2010	[104]						X	X	X		X					X				0	0	2	1	2	5
	[45]				X		X													0	1	1	0	0	2
	[110]						X		X	X										0	0	1	1	1	3
2011	[101]					X														0	1	0	0	0	1
2012	[131]						X			X			X		X	X	X	X	X	0	0	1	0	7	8
	[138]											X								0	0	0	0	1	1
	[20]		X		`			X							X	X				0	1	1	0	2	4
2013	[21]	§		X	X				X	X										0	2	0	1	1	4
	[134]										X									0	0	0	0	1	1
2014	[117]			X			X	X	X											0	1	2	1	0	4
	[97]					X	X		X		X									0	1	1	1	1	4
	[90]			X	X	X	X	X	X	X	X					X		X		0	3	2	1	4	10
	[63]		X			X	X	X		X	X		X	X	X	X	X	X	X	0	2	2	0	9	13
	[128]						X					X								0	0	1	0	1	2
2015	[84]			X	X	X														0	3	0	0	0	3
	[105]						X	X	X	X	X				X	X				0	0	2	1	4	7
	[98]					X			X	X										0	1	0	1	1	3
	[121]								X											0	0	0	1	0	1
	[116]							X												0	0	1	0	0	1
	[93]			X				X												0	1	1	0	0	2
	[89]			X	X				X		X									0	2	0	1	1	4
	[107]						X				X									0	0	1	0	1	2
	[87]			X		X	X													0	2	1	0	0	3
	[88]			X	X	X			X											0	3	0	1	0	4
2016	[139]											X								0	0	0	0	1	1
	[102]					X			X		X			X						0	1	0	1	2	4
	[64]	X						X							X					1	0	1	0	1	3
	[112]						X				X									0	0	1	0	1	2
	[122]								X		X									0	0	0	1	1	2
	[126]								X		X									0	0	0	1	1	2
	[28]						X		X											0	0	1	1	0	2
2017	[68]	X					X													1	0	1	0	0	2
	[115]						X							X		X				0	0	1	0	2	3
	[109]						X				X									0	0	1	0	1	2
2018	[127]								X											0	0	0	1	0	1
	[83]		X				X													0	1	1	0	0	2
	[6]								X											0	0	0	1	0	1
	[136]										X									0	0	0	0	1	1
2019	[69]	X			X															1	1	0	0	0	2
	[70]	X		X		X			X		X									1	2	0	1	1	5
	[71]	X					X	X	X											1	0	2	1	0	4
	[123]								X		X									0	0	0	1	1	2
	[106]						X		X		X									0	0	1	1	1	3
	[129]								X											0	0	0	1	0	1
	[135]										X									0	0	0	0	1	1
	[137]										X									0	0	0	0	1	1
	[72]	X							X		X									1	0	0	1	1	3
	[73]	X					X				X									1	0	1	0	1	3
2020	[79]	X				X			X											1	1	0	1	0	3
	[124]								X											0	0	0	1	0	1
	[77]	X																		1	0	0	0	0	1
	[74]																			0	0	0	0	0	0
	[75]	X																		1	0	0	0	0	1
	[76]	X				X	X													1	1	1	0	0	3
2021	[78]	X																		1	0	0	0	0	1
		18	6	15	10	21	31	19	39	16	34	8	6	5	12	18	7	4	7					
		18	52				50		39	117														

The reference details for all 86 publications can be found in the table with the corresponding reference ID. The third column shows which publications referenced 3PL operators and WMSs research together, and the following columns reveal different research areas to which the specific publication contributes. In the following parts, we explain the deeper details in Table 1. In short, the table visualizes the categories of subtopics and four main topics of the 86 publications. The first main topic connects WMS to warehouse characteristics, and the other three are devoted to WMS taxonomy, functions and features, and deployment issues. Each main WMS area contains area-specific subtopics with the number of contributed publications. All discussed subtopic areas in these 86 publications were put into similar groups and topics. Counted connections in studies show the significance of the work and its contribution to the 3PLs and WMS context.

Table 1 can be interpreted in several ways. Firstly, 86 sources were grouped according to publication years, and there are clear historical trends in publications. Especially researchers have demonstrated more interest in WMS-associated topics in recent years than earlier. Additionally, the area-specific numbers of WMS taxonomy and features topics still have a steady interest compared to warehouse characteristics and WMS deployment issues. Interestingly, warehouse characteristics score fewer mentions in the found literature in comparison to other topics. Noticeably, the subtopic of WMS integration with other automation and communication systems has recently been increasingly recognized in most studies on the main topic of WMS deployment.

Secondly, the two horizontal bottom rows in Table 1 show how the selected literature contributes to the named main topics and subtopics. The bottom row depicts the total sum of links from different studies, referring to other WMS main aspects. In contrast, the row before shows the separate count of the references to the individual subtopics. This indicates the number of references to that specific subtopic in the analyzed literature set. The summary allows a fact-based numeric comparison of the literature on different subtopics under the main topic areas. Based on the numbers alone, “WMS functions and features” is the least discussed main WMS-related topic area (39 references).

Interestingly, the WMS taxonomy had a wide range of references (50), but only two clear subtopics and discussion directions were found within that main topic. This might indicate a narrow view in the WMS taxonomy area, showing a need to widen the research scope. Thirdly, in the last vertical column on the left, the numbers of subtopic areas under the main topics were separately counted for topics and sources. For example, in [21], one can see a total of four mentions of the evaluated main topics and subtopics connections. Additionally, this study has neither reference to 3PL nor a discussion of WMS taxonomy.

Reviewing the last vertical columns reveals a scarcity of research to discuss or involve all four topics related to WMS. Only four of the 86 sources touch on all four WMS main topics (a high evaluation score and significance for the specific literature). These four publications are specially color-coded with dark grey and highlighted with a dashed line in the table. The other publications lack links (mentions) to at least one of the four available topic categories. Those findings show a specific theme between observed research links on the topic areas and WMS studies in the 3PL context.

In conclusion, WMS has yet to be studied from a holistic point of topic view. From the numeric analysis point of view, if a reviewed source had discussed all the specific aspects available under the four main topics, the number of points assigned would have been 17. Only seven sources (a bit more than 8%) received five points or more but less than 10, and only a total of five references (less than 6%) were assigned 10 points or more. In sum, over 80% of the sources had a tight and narrow focus on discussing only specific WMS matters. Thus, it is hard to identify published materials addressing these topics from a broad perspective of WMS and 3PLs. Only a few studies discuss WMS as the main subject from multiple perspectives simultaneously. This finding points out the necessity for further research while pointing to a high-level research gap in WMS studies.

All 86 sources referencing to 3PLs and WMS and four WMS main topics and their subtopic areas were analyzed and scored in the same manner. The following sections address the most critical discussed content within the five main topics and topics-subtopic areas.

3.1 Reference to 3PLs and WMSs

All 86 publications were evaluated based on their references to 3PLs and WMS context areas. From 86 selected literature, only 19 studies mentioned both 3PLs and WMS [60-78]. All these studies formed a separate group of publications referencing 3PL and WMS.

There were no mentions of 3PLs using WMSs, but there were no mentions of both terms together [72,73,76]. For example, 3PLs were mentioned as one actor for reverse logistics [72] and the one to whom companies outsource and transfer their business operations for optimizing activities [67]. In this way, 3PL does warehousing operations for the account of business customers [63]. Logistics service providers have yet to adopt recent information technologies [73]. For example, WMS is one of the challenges of digitalization declared in 2019 for the transport-forwarding logistics sector in Poland [78]. The research of [77] aimed to identify the service packages offered by logistics operators leading to the greater efficiency of logistics service providers, where WMS is only a variable in the analysis. In [76], WMS should communicate and synchronize inbound and outbound shipments for effective cross-docking practice. Also, [69] mentions 3PL and WMS, however, the focus point of the

study focused is to improve the genetic algorithm for warehousing.

Also, it was mentioned that 3PLs could advance in their business efforts through WMS utilization. According to warehouse experts, a 3PL should implement WMS to efficiently and effectively perform warehouse logistics activities [62]. For instance, logistics service providers can combine the data from various systems such as WMS, Enterprise resource planning (ERP), and transportation management system (TMS) and collaborate with these systems providers to obtain competitive dynamics of the logistics service industry [75]. Besides, as found software providers adapt their WMS design and functionality for the 3PLs' needs [65]; for example, if a 3PL needs to be flexible in changing customers' order mixes and types, they can easy access WMS via online [60] having visible data about warehouse processes and operations [61].

Besides, a couple of studies discussed the design of WMS, especially for 3PL [60,66]. For example, [79] reports a 3PL company case utilizing drones for an effective stock-take method mentioning the difficulty of integration with the current WMS. Also, [66] named wholesalers as potential WMS users apart from 3PLs.

There is also a discussion about information systems in omni-channels for logistics service providers to use [71]. [70] describe the digital twin of WMS developed to demonstrate different work scenarios suitable for WMS. [68] discuss the case of a logistics service company in the Republic of Croatia that uses WMS for managing warehouse operations and processes. In addition, [64] reports 3PLs for deploying a cloud-based WMS to save time and nearly immediately handle warehousing operations for new clients. At the same time, [74] builds a framework for an Italian 3PL to introduce a new storage assignment policy and reduce the traveling time for order picking in warehouse performance improvement projects. Overall, 17 contributions totally to this topic are not much, still missing a solid connection and vivid emphasis from the academic research point of view on 3PLs using and selecting WMSs.

3.2 Warehouse characteristics as a basis for WMS

This section focuses on warehouse characteristics discussed in the literature to be significant for WMS. Table 1 includes four main warehouse characteristics and related subtopics: warehouse type, operational specifications, physical parameters, and automation systems. In the following, all four subtopics are discussed separately.

3.2.1 Warehouse type

Within the found literature, only six out of 17 sources were related to warehouse-type/style as an essential factor for WMSs. A warehouse's processes and activities identify its distributional or productional type [20,80]. Specifically, distribution warehouses may have high order volume and complex business processes [81]. In contrast, production warehouses store raw and/or semi-finished products to be used later in manufacturing [82]. Also, warehouse types derive from stored product category purposes such as sorting centers for letters and parcels, cross-docking for perishable items, and e-commerce fulfillment, consolidation, and transshipment break-bulk warehouses (e.g., automotive parts) [63]. [83] describe a particular warehouse type called a public warehouse (commercially serving different clients). In such a warehouse, multiple companies get warehousing services without hiring their staff or using resources as a ready-made logistic management and service platform.

3.2.2 Warehouse operational specifications

Warehouse operational specifications are a subtopic discussed in 15 different literature sources. Strategic warehouse planning and operating policies are essential to warehouse operational elements [84]. Proper warehouse management includes knowledge of warehouse organization, processes, and resources [85]. Here, processes include goods receiving, storing, order picking, packing for dispatching, documentation administration, and other value-adding logistics services [21,85-88]. Stock-keeping unit's (SKU) storing restrictions as physical (sizes, shapes, and weight dimensions) [45,89] and environmental (flammable, frozen, and hazardous) [90] pose requirements for warehouse design [91,92]. The warehouse performance indicators and task complexity are measured in the number of SKUs, handled order lines per day, and the various processes [21,90]. Additionally, the warehouse's operating capabilities depend on its capacity utilization rate, associated with the number of processed order lines.

Well-defined warehouse key performance indicators (KPIs) are connected to overall warehouse logistics performance capability and metrics, specific process department assessments, and equipment technology performance levels [84]. For instance, [70] define KPIs such as warehouse buffer utilization rates, picking order traveling, and temperature stresses distance. Other warehouse performance determinants include warehouse resources (the technical equipment utilized in warehouse processes and storage) and warehouse personnel (people assets in the warehouses) [85,89]. The warehouse layout and size also determine the effect on the complexity of warehouse performance [82].

Following the recent e-commerce trend, warehouses are increasing in size [93]. Warehouse's process documentation flow [85] and control policy [89] should be carefully deemed too. Work scheduling and health issues (psychological, ergonomics, safety) concerning warehouse personnel must be considered [84] as part of the workforce caring models. Furthermore, according to [94], a WMS should also suit the customer's warehouse parameters to design WMSs based on warehouse prerequisites [85] systematically.

3.2.3 Warehouse physical parameters

The topic of the warehouse's physical parameters is addressed in 10 different sources. For example, wrong picking and storage area zoning, layout design, and storage policies could lead to problems in space utilization [84]. A poor warehouse layout hinders productive operational performance and generates inefficient space usage, unwanted additional costs, warehouse performance complexity, and increased picking time [21,45,82,89]. Picking time consists of three different time components: traveling from one to another SKU, actual picking, and other associated activities [69]. An outline of the warehouse can offer an optimal decision parameter for processes planned to allow adequate warehouse storage capacity [95].

Other benefits are practical and effective allocation and handling of product storage area, input and output points for receiving and dispatching products, and easy access to products from picking aisles [85,88-90]. For instance, despite WMS's role in optimizing warehouse storage, [69] emphasized that the role of proper goods placement can result in a 60% picking time reduction. Modern WMS can use traditional ABC analysis and genetic algorithm-based approaches to relocate inventory and shorten picking distance.

Warehouse layouts vary from a traditional rectangle with parallel straight aisles [90] to more modern and even innovative layouts design such as v-shaped cross aisles, a flying-v, or chevron, and warehouses with fishbone-like aisles [89,90]. Figure 1 depicts the differences in the layouts.

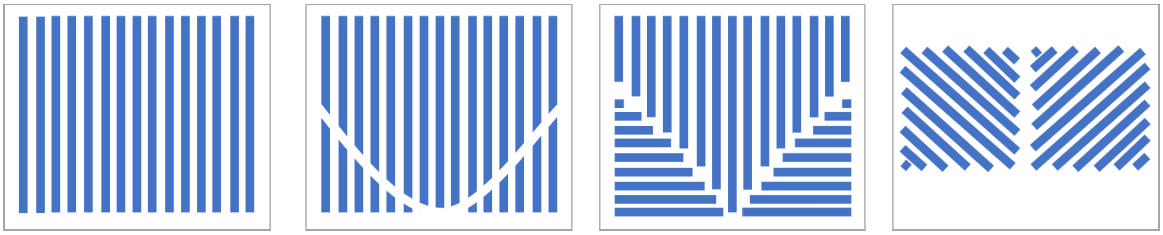

Figure 2 Warehouse layouts (from left to right): a traditional rectangle with parallel straight aisles, Flying-V, Fishbone, and Chevron)

3.2.4 Warehouse automation and automated system descriptions

The most discussed warehouse characteristics (in 21 sources) relate to automated warehouse systems. Software and hardware are common technologies installed in a warehouse [84]. Deploying advanced technologies is an ongoing trend to decrease data errors [96] and reduce the increased complexity of warehouse tasks [97] through hardware systems [82], so customers refrain from stock depletion, overdue deliveries, and backorders [44].

Today, portable mobile terminals [98] and next-level advanced technologies with real-time instructions [90] assist a warehouse picker via, e.g., light-directed indicators for put-to-light and pick-to-light [85], pick-by-voice, and virtual display picking systems. Other helpers are automated product-to-picker storage and item retrieval system (e.g., automated cranes), picker-less systems (automated dispensers and robots) [85,97,99], and frequently deployed AGV [84]. In addition, automated data collection equipment facilitates data exchange using supportive data capture technologies [70] such as RFID [96], barcoding [95,100,101], and different sort of robotics [63,87,88]. With the help of automated data collection, especially for a cross-docking facility, warehouse data can be captured accurately and continuously without manual data entry [76]. Other examples of technology-based solutions are horizontal and vertical carousels, frame dispensers, and other automated rack systems [85,97]. However, in the opinion of warehouse managers and senior consultants, adding more automation to warehouses causes a reduction in warehouse flexibility [84]. For WMS efficiency, all hardware and automatic measuring devices should be integrated into a WMS for information flow and operations optimization [86,91]. Additionally, in [79], drone technology checks pallet IDs in a warehouse; however, this approach faces difficulty in the process of integrating drones with WMS for matching stock activities. Discussing futuristic warehousing, [102] suggests 3D printers for on-the-fly items and parts production.

3.3 WMS taxonomy

The topic of WMS taxonomy is discussed in 42 sources. These sources reflect two main directions. The first includes the definition of WMSs, and the second cover different WMS types. Within the found literature, the majority focused on WMS definitions (31) and less studied categorization of WMSs with different types (19). Eight sources touch upon both WMS definition and categorization.

3.3.1 WMS definition

Generally, a WMS supports and enhances the functionality inside warehouse tasks through IT and automated services to communicate real-time inventory and resource information [80] and bring warehousing to the next level [103]. There are two approaches to the WMS definition in the selected literature. In the first, WMS solutions are considered "just another software", while in the second view, WMS is seen from a holistic point of

view, where scholars deny its simplified interpretation toward more being a leading cause for changes in the company's warehousing operations. The authors' literature points of view can be divided into two separate groups. The first group (16 studies) considers WMS as a computational system to control the warehouse's "physical activities and arrangements" [104] from order execution to fulfillment [82,90] to utilize warehouse resources, equipment, workforce efficiently, processes [45,87,105] and transport [106]. With WMS support, operational targets can be achieved faster and more accurately [92]. WMS manages internal warehouse subsystems [97,107]. Namely, a WMS collects, registers, and manages data about warehouse inventory activities and processes [68,71,108,109] and identifies possible errors and improvement areas [110], adding transparency to all orders, delivery processes, and activities [106]. Also, a WMS offers design guidance for picking lists, goods allocation, order division [111], instructional documentation [112], and recognizes customer order patterns [94]. WMS as a material tracking tool rather than a decision-making one [83]. WMS is a data analysis system supporting warehouse IT management decisions [68]. The second group (10 different literature sources) considers a WMS as a combination of IT products and a complete project management tool for operational development in technology and the workforce [113]. Assigning an operating team and creating stepwise guidance for WMS implementation and intelligent systems installation [96] is essential [114]. Such project management starts with a documented function request list from a WMS vendor [63, 103]. Additionally, these authors count a WMS as a mini enterprise resource planning (ERP) system designed specifically for managing and optimizing warehouse activities. So, warehouse key processes can be more transparent [73,76,86,114] with blended information and material flows [113]. [115] extends a WMS definition to an overall system whose activity scope exceeds physical warehouse boundaries.

3.3.2 WMS types

Within the WMS taxonomy referencing literature (36 sources), three main discussion lines are based on WMS software solution aspects: 1) type, 2) provision, and 3) functionality scope. Here, in terms of software system types, a WMS can either be tailor-made to meet a set of unique requirements and developed from scratch or a standardized off-the-shelf package configured with a set of functionalities to solve frequently repeating needs in different warehouses [66,67,80,82,105]. The diversity of warehouse products and processes and SC uncertainty dictate the requirements of a more highly customized WMS [90]. A WMS should have a specially designed technical structure, operational framework, and system control [86]. Moreover, a customized WMS is developed especially for businesses to gain a competitive advantage by differentiating warehouse operations from their competitors [65]. According to the literature, a noticeable new trend is occurring, as WMSs were initially built and highly customized [67]. Still, in recent years, demand has been increasing for more standardized off-the-shelf WMSs [60,105]. The wrong decision to install either a standard WMS or a customized WMS can lead to high costs, lost time, and loss in company competitiveness in warehousing activities [82]. A WMS can also be used as a plug-in module within ERP systems to perform at least some of the typical WMS functions [104], not delivering as many benefits as a complete WMS does (e.g., enhanced productivity, minimized errors, and space-efficient warehouse storage allocations [71,100,116].

Based on the literature [60,63,64,67,71,117], three typical WMS implementations are: 1) standalone (installed and hosted at a customer's premise for long-term usage); 2) Software as a Service (SaaS) (implemented on a system provider's server rented to different customers) [67] and 3) cloud-based solution (a vendor operates hardware and software, while clients access WMS via a web interface/system integration). Other authors [60,63] also identified web hosting as a new WMS deployment method. According to [112] Golinska (2014), cloud-installed WMS provides process standardization, remote control, and lower operational costs. Besides, web-enabled WMS can be integrated easily into other SC systems [60]. [64] discusses more cloud and premise-placed WMS types and their specifics. In the next five years, retailers plan to put more weight on utilizing cloud-based WMS types [71].

In addition, based on the system functions' scope and complexity, WMSs can be classified into three subcategories. For example, WMS's functions could be basic (recording inventory status and location information), advanced (planning and monitoring the warehouse's resources and activities in addition to basic WMS functions), or complex (fully optimizing the warehouse's operations with the help of automation and value-adding planning) [20,82,118]. Discussing the complex systems, [65] references best-of-breed WMS providers specializing in the needs of both small and large companies and offering different WMSs (traditional licensed, low-cost, small, and on-demand solutions). Notably, all the mentioned system scope and complexity-based subtypes of WMS are presented in the survey of warehouses and distribution centers [93].

3.4 Warehouse functions and features as discussed in the literature

WMS functions and specific aspects were covered in 39 sources with explicit and not exploration of WMS functions. Most literature sources (21) discuss the benefits of WMS functions assisting with installation and implementation rather than naming exact functions [6,21,72,79,82,88,89,94,95,105,106,110,111,114,117,119-124]. Twelve sources studied WMS functions comprehensively [60,71,80,81,86,90,91,96-98,104,118,125]. Four studies [98,104,118,126] compare WMS functions to other logistic software systems.

In the research by [82], the authors distinguish three types of WMS functional categories: 1) inventory analysis as quantity tracing and associated documentation; 2) warehouse management of processes, resources, and reporting; and 3) warehouse execution functions assisting in managing logistics flows inside the warehouse. However, the scope of WMS functions is more on warehouse operations than resources because the final decision on the utility of recourses is left to the warehouse manager [110], as a WMS just controls all warehouse activities from SKUs arrival until shipment [122]. WMS functions are designed for warehouse replenishment [102,111,119], order picking, and storage options [86]. Significantly, a WMS optimizes operations greatly in the case of mixed single and batch-picking methods [123]. A WMS, together with automated warehouse solutions, supports inventory picking-up processes [90] and accelerates goods sorting and packing activities [95], prioritizing critical order fulfillment and close delivery destinations [123]. [70] develop a digital WMS twin to combine other research on WMS modules and warehouse operations. WMS is also found to play a vital role in e-commerce logistics for real-time monitoring, management, maintenance, and scheduling information for warehouse logistics [124] and real-time shipment and receiving status notifications [126]. A WMS facilitates inventory and data visibility [79] because of records transactions of order numbers and quantity anomalies [6]. WMS can provide information on picked orders, receipts, returns, and SKU numbers to verify the accuracy of system inventory records [127]. Based on the literature, customers demand WMSs to support cross-docking material flows, what-if scenarios, and postponement strategies [60]. A WMS should allocate products via IoT for paperless information exchange [21, 88] with web technology-based interfaces for different user groups [121] and advanced shipment notices about the status of materials [80]. Moreover, a WMS can aggregate and consolidate shipments sent to and from a warehouse into a truck [106]. One standardized WMS function is to support picking algorithms such as FIFO, FEFO, FMFO, and LIFO [71,106,127].

In documenting day-to-day warehouse operations [91], a WMS can perform recording functionalities such as SKUs cycle accounting [71,96,114], damages, and operational mistakes [117]. Moreover, an advanced module in a WMS can be added to manage the warehouse routing optimization in SKU picking activities [89].

Vendors try to widen the range of WMS functions by adding transportation, yard, and order management modules to give WMSs more power [60,102] to design systems for 3PLs' needs [65]. Meanwhile, other advanced secondary WMS functions cover SKUs inspection, audits, quality measurement, and essential reporting associated with labor management [80]. A WMS can provide advanced functions for inventory replenishment, cycle accounting [128], and business strategy optimization [97]. [125] indicates that WMS help in mitigating problematic consequences of any returns via discipline, automation, and repeatable actions and makes performance reports such as inventory, equipment, and warehouse space utilization [104], single transaction expenses [106], and inventory location maps [129].

Developing a framework for reverse logistics operations, WMS has a role in calculating and optimizing storage space, time, and costs required for returned goods [72]. Among WMS functions, the system informs warehouse resources and labor equipment rate utilization [120] and analyses customer orders to forecast required SKU levels. As a result, a WMS increases inventory accuracy [94] and minimizes the amount and upstream inventory [105]. Most typical WMS functions to implement in the next five years include added reliance on cross-docking, advanced near-future inventory plans for optimized receiving and decanting operations, new picking strategies with dynamic and static picking locations, and novel mobile units plus integrations in shipment schedules synchronization [71].

3.5 WMS deployment considerations

Most WMS deployment literature considers deployment issues from the successful implementation and operation use point of view (41 studies). The research on this topic was quite broad, as the analysis divides the WMS deployment topic into ten different subtopics.

3.5.1 WMS fitness to business, scalability, and modularity

Several sources point out a need to understand the company's business operations before making a WMS investment and development. Basically, a company should select a WMS considering its business complexity realities [21], process flow, and requirements of operational capabilities [67,80,82,90,114,130,131]. In turn, a WMS provider should fully understand the previously mentioned issues [63] rather than persuade customers to change warehouse activities for a WMS [103]. Furthermore, [86] and [63] urge to assess WMS scalability for the possible new modules added to meet future business needs. At the same time, a WMS vendor should have a solid knowledge of the business processes and operational possibilities of different customers and future WMS operational potential [132].

Investing in WMSs, companies should decide upon proper warehouse material handling equipment and allocate their resources and labour for their own needs [110], e.g. SKUs' characteristics, such as quantity, size, weight, and temperature conditions, are essential factors [92]. Plus, a WMS should suit the client's warehouse type [98,105] and support the warehouse's operational processes and functions [86].

3.5.2 Integration with logistics automation and communication systems WMS fitness to business, scalability, and modularity

This subtopic had the highest number of sources-based connections (34). The reviewed sources emphasized WMS's integration with other systems and subsystems [86,105] and other software products [132] for future business growth possibilities [80]. Data and event messages between systems should be transferred in the same standardized format and structure [100,130], allowing the accurate and precise exchange of essential business data [133] via open or standardized interfaces [98]. As stated in one retail company survey [71], less than half of the companies utilize direct real-time updates and information synchronization operations in their WMS solutions. However, the rest do this, e.g., only on an hourly basis. Moreover, WMS benefits from integrating system users into other SCs for additional knowledge-based optimization [112]. [70] bring up an interesting issue called the product intelligence paradigm, especially how a product's physical entity relates to its informative content, WMS should have all input information and data sets from its customer, such as correct order numbers and goods capacity.

From a practical point of view, choosing a WMS that can interplay with an ERP system makes sense to avoid additional investment costs [91] and boost the system's performance figures [97]. The obvious benefit here is more accurate long-term activity planning [82,104] with a better transfer of customer order queues [86,98].

With an ERP system, WMS can integrate capacity and demand planning systems to achieve JIT operations [72]. A standalone WMS can integrate with an ERP via EDI [71] messages. An ERP integrated with WMS shares prioritized urgent orders. A WS can also be combined with a transport administration system [123] and TMS to exchange core data [44,98] for SC-level process optimization purposes coordinating vehicle load and schedule plan activities [102,106], shipping and transportation [60], and exchange warehouse and transport activity information [94].

A WMS integrated with a warehouse control system gets greater power over automated system machines in the warehouse [102], while a warehouse execution system optimizes the warehouse's resource usage [107,112]. RFID and barcode technologies exchange inventory data with WMS [104], which is added to an electronic product network [126]. Other warehouse subordinate systems for WMS integration include forklifts and hardware peripheral devices for material handling (e.g., barcode readers [113], RFID scanners and computer terminals [98], label printers [82,102], conveyor systems [60], voice, light, and virtual displays and order-picking control equipment [60,63,90,93,134].

[122] studied integration and constant communication of voice-picking technology and WMS supplying files with item data, location, and operation tasks. A WMS can interface with material planning and manufacturing execution systems [60]. [135] address implementing RFID technology in WMS for technology-based benefits over barcodes used on product-level scanning. A robotic arm with RFID reader solutions over a conveyor belt can help to modernize work practices and boosts information transparency [136]. [109] were the first to discuss about network/video stream technology, named as a video management system, to be integrated with WMS. [137] gather various WMS integrational cases of IoT, RFID, augmented reality, and cloud-based systems in the literature.

[73] strongly emphasize the role of IoT implementation and integration of WMS with all sensors on a warehouse in/out gateways, forklifts, shelves, heating ventilation, and air conditioning system to transform all this data into useful information (e.g., energy consumption, inventory, and warehouse safety) and plan of actions. Business information and SC dynamics should be united to align integration and system capabilities with 3PLs. The first recommended step is to create an SC enterprise architecture to become the foundation for all logistics systems' selection, investment, and implementation decisions [99].

3.5.3 Warehouse database integration

Based on the literature, a common central database is required for WMSs and execution systems [80,100,130,138] to support warehouse processes and activities [67]. The critical ingredient for efficient WMS is good data input, such as storage policies, operations flow, and operational performance capabilities [86,108]. Warehouse operational data (e.g., pallet naming system and SKU identification schemas, among others) can differ between warehouses causing global WMS integration challenges [139].

3.5.4 WMS user interface

As the language heavily affects the operational suitability of the human-computer interface, it should be in the users' native language to minimize the possibility of misinterpreting the content of the instructions. At a minimum, the language used in a user's interface should be native to the activities and processes at the warehouse; additionally, all processes should follow the same general pattern for language and terminology [86]. Additionally, WMS should be easily accessed remotely via the web [63]. In other words, having a web access configuration is a vital functionality in today's WMS [130]. A user coordinates warehouse activity by logging into the warehouse's internal database knowledge query system [99]. Operability characteristics and customization designs for the user interfaces still need further studies [80,131].

3.5.5 WMS replacement

The two main ways to replace a WMS are 1) new WMS onboarding together with the old system and 2) direct replacement of an old system [86]. The second option is

favorable when a customer launches a new WMS to stabilize warehouse material flows [63]. The literature sources [132] and [102] state that old IT platforms may be replaced due to WMS's inability to respond to changes in a customer's business model, growth in business activities, or new business-related requirements. These account for fundamental factors leading to customers' willingness to upgrade a WMS. Current WMSs may also be replaced due to age, lack of support for old software, or a heavily customized solution that cannot be upgraded [102]. In the [115] research, an analysis of old WMS serves as a basis for designing and implementing a new WMS.

3.5.6 WMS implementation time and cost

When implementing a WMS solution, required software installation time and financial costs should be studied broadly before making investment decisions [20,82,105,113,130]. Also, companies should understand how a new WMS will affect their administrative operations [131].

The implementation time required for WMS setup depends on the integration of the current systems [96] and WMS customization or standardization [82,105]. A WMS implementation cycle can vary from three months for small systems to nearly 30 months for complex systems [20,98]. There should be a stepwise WMS launch with contingency planning [80] with pre-installation performance testing [96]. In case of system adjustments, there should be a time buffer of several months [86,131]. Moreover, a WMS should be tested with complete information and sensor input loads during the quietest operational time in the warehouse [63].

In some cases, a system's implementation and updating cycle never actually ends, as the system is in a continuous/constant development cycle over its entire lifetime; this development time might even exceed the system's operational lifetime [98]. On a customer's premise, a traditionally deployed WMS's lifetime is 15 years or more [64]. At the same time, WMS vendors are under constant pressure to implement new solutions for customers as quickly as possible [60]. This might indicate shorter WMSs lifetimes in the near future, more upgradable design choices, or a move towards SaaS (Software as a service) / Cloud service.

On the costs front, WMS solution providers should predict all system installation time-related costs. In the 1990s, the average WMS prices continuously decreased due to healthy market growth [60]. Notwithstanding, WMS implementation includes multiple expenses related to software installation and system maintenance, development, and updates [63,130,140]. Other warehouse equipment costs include purchasing sensor and technology equipment like barcode readers, hardware infrastructure, and printing identification cards [115]. [115] presents a list of software and hardware costs in WMS implementation. Different license WMS costs come from IT services are user ratio per terminal, transactions, annual or monthly base service, and professional integration [86,98,104,131]. Other costs account for designing the host interface [96], positioning forklifts and digital users' identification [104], warehouse personnel training [80], and integration with other systems [104]. Traditionally, WMS providers decrease implementation costs by leveraging offshore programming talents and the Internet as a software distribution tool [65]. As expected, implementing a highly customized WMS takes more effort and money to maintain than off-the-shelf WMS solutions [60]. Replacing an old WMS with a new one reduces costs associated with employees and warehouse equipment [115]. There are three known WMS payment models for clients: SaaS, on-demand (a multi- customer arrangement where a customer pays only for the time of WMS usage), and a hosted software option (software provider installs a WMS either at its premises or the customer's and manages a WMS ultimately) [125]. Despite the costs, a WMS is still a favourable investment for 3PLs to optimize operations, reduce labour costs, improve overall efficiency, and minimize errors [90,114].

3.5.7 WMS vendor support service

WMS installation and after-sales original investment services are essential components to consider in WMS implementation projects [63,131]. A compelling argument for vendor selection is attention to training assistance and procedures [80,86,100] in the supplied documentation, manuals, and handbooks [86,96,140]. A WMS vendor should also be assessed based on contract and guarantee duration [80] and provided help-desk services [82].

3.5.8 WMS quality verification

WMS customer service includes a system quality examination [90]. Clients benefit from WMS vendors' routine software updates and quality validation cycles [63]. Besides, a software vendor following international software quality standards should be considered a better partner [131].

3.5.9 WMS vendor reputation

WMS vendors' reputation comes from the industries where it has operated, provided software, and has experience supporting WMS implementation projects [63,131,140]. This experience is a mix of served client warehouse types, SKU categories, and warehouses' degree of manual labor vs. used automated equipment [86]. The stability of the vendor's operations is reflected in the success of its WMS installations and operational use [96], feedback from clients of past installations, and years of business operation [80]. The vendor's creditworthiness can be measured by the worldwide presence of the company/software offering [130].

4 Discussion

This study has systematically mapped the literature on WMS characteristics relevant to 3PLs selecting such

systems. With the proper understanding of WMS-related specifics, 3PLs could better choose a WMS and improve customer service. The goal was to understand the current state and direction of research in WMS characteristics and 3PL context. Based on the findings surfacing from the SLR process, we now answer into the set RQs.

Regarding our answers to RQ1 - What are the WMS characteristics discussed in the literature relevant for 3PL warehousing activities involved in selecting WMS activities, we provide Table 2, presenting the identified WMS and 3PL reference and WMS-related topics and subtopics in our analysis based on the 86 literature sources on 3PLs and WMS selection. 17 studies are mentioning 3PL and WMS; however, not all studies directly reference 3PL using WMS. For WMS, 17 subtopics were identified (in italic letters) and noticed to be unevenly distributed under the four main topic areas (in bold capital letters). For example, 10 of the 17 were under the main topic of "WMS deployment considerations"; however, "WMS functions and features" had only one subtopic area in the analyzed literature. Identifying the 17 subtopics and their uneven distribution leads to the RQ2 answer. This question looks more closely at the directions of the studied literature. Thus, the subareas that produce new knowledge can be identified where researchers might fill gaps left in the WMS and 3PL research cross-section.

Table 2.SLR topics and related subtopic areas

MAIN TOPICS		**WAREHOUSE CHARACTERISTICS FOR WMS FUNCTIONALITY (52)**				**WMS TAXONOMY (50)**		**WMS FUNCTIONS AND FEATURES (39)**	**WMS DEPLOYMENT CONSIDERATIONS (117)**			
SUBTOPICS	**REFERENCE TO 3PL OPERATORS AND WMS (19)**	*Warehouse type (6)*	*Warehouse operational specifications (performance, processes, SKUs characteristics, order lines, etc.) (15)*	*Warehouse physical parameters (size, layout, etc.) (10)*	*Warehouse automation systems description (21)*	*WMS definition (31)*	*WMS types (19)*	*WMS functions and features (39)*	*WMS fitness to business, scalability & modularity (warehouse characteristics, functions & processes) (16)*	*Integration with logistics automation and communication systems (34)*	*Warehouse database integration (8)*	*WMS user interface (6)*
									WMS replacement (5)	*WMS implementation time (12)*	*WMS costs aspects (18)*	*WMS vendor support service (7)*
									Quality verification (4)		*Vendor's reputation (7)*	

Continuing with the RQ2 - What is the current focus of 3PL logistics selecting WMS, the largest group of subtopics fell under "WMS deployment considerations," identifying it as the most focused area for WMS selection considerations. In contrast, a minor focus fell under the "WMS functions and features" with only one subtopic. From this study's point of view, "WMS functions and features" seem to be a focus area that needs further research because of the functions' broad scope. WMS deployment needs additional research on the newest technologies and innovations on the hardware and software side. From the point of view of 3PL operators, it is easy to see how added knowledge about the newest technology solutions and operations enhances functions. These aspects are also highly valuable considering new WMS investments.

Most of the literature was narrowly focused, without multiple viewpoints or simultaneous WMS topics and aspects connections. 3PLs should view the big picture encompassing system implementation and investment considerations. These actions should be undertaken to support 3PLs in business process development and efficient IT management via additional research to connect broad, high-level views of this topic with more detailed subtopics. More research will help close the research gaps

on WMS and other related systems integration into business plans, allowing new knowledge on the relationship between IT, organizational performance, and structures.

The RQ1 findings and previously mentioned practitioners' needs support our steps towards RQ3 - Are any relevant WMS aspects that need to be added to academic research on 3PL warehousing operators selecting WMSs? To study the specifics and evaluate what might be missing in the literature, we collaborated with a well-known, award-winning, and technically frontline-oriented 3PL operator to help us answer RQ3 by comparing their views with our research findings. Thus, the literature only covers some of the WMS technology deployment issues, and some new research areas are appearing. Moreover, the 3PL experts mentioned these as fundamental aspects from a practical point of view. Some examples referenced WMS control issues and information exchange considerations between systems missing discussion in the academic literature, where several communication protocols are required. Therefore, we suggest new research on those areas and follow-up research with 3PLs to cover other aspects/subtopic areas, for example, sustainability [141] and evaluation aims [142,143], which might reveal additional missing subtopic aspects. Consequently, these aspects should add more value to the WMS selection done by 3PL, as these systems significantly influence warehousing activities.

5 Conclusion and future research directions

The present study was designed to investigate research performed in WMS and 3PL context, to synthesize and systemize knowledge on this topic, to identify current research status, and to define future academic research directions based on the 3PLs validation review. Our research findings offer several contributions in both academic and practical words, enhancing the topic of WMSs used by 3PLs.

In addition to mapping topic literature, a novel and holistic view of 3PL warehousing operations in the context of WMSs is also provided. The current findings add to the growing literature on this topic and demonstrate the exact research gaps/scarcity of research for further study directions in this cross-sectional area.

This study provides the system knowledge-based decision for practitioners and executives in fast-changing management system markets. As for practical implementations, the structured findings of our research can work as a baseline for constructing a WMS evaluation framework for systems selection and deployment matters. Gathering WMS materials, our work helps make comprehensive framework(s) to assist with well-educated WMS-related decisions. This information can also be used for the educational purposes of 3PL warehouse and seasoned managers to utilize the information for recruits. Growing talents' educational material as warehousing is among the 12 key topics in studying SC management [144].

The scope of WMS functions needs to be researched more as the current literature does not answer clearly, e.g., how to divide different functions into clear classes for WMS selection purposes. For 3PL practitioners, this area-related research could help practitioners make even better decisions and enhance business intelligence.

The RQ3-related fieldwork revealed research gaps in the newest WMS features and technology integration possibilities. Area specialist interviews indicated demand for WMS and sustainability knowledge as WMSs already manage decision-supporting systems and analytical reporting of current sustainability levels of 3PL operations. Besides, 3PLs are essential in orchestrating warehouses [145,146] and SC decarbonization [32]. As a note, previous studies suggest a 15-year WMS lifetime, which seems highly unlikely compared to fast software development cycles created by global digitalization activities leading to a need for more precisely defined system lifetime expectations.

The interviewed 3PL operator pointed out WMS deployment issues not discussed in the reviewed literature, indicating a need for additional studies and collaboration with a broader 3PL operator base to map any uncharted territory for future research. An acknowledged limitation of the study is global generalizability, even when we have used internationally operating practitioners and academically educated specialists to evaluate our work. Since these consulted company experts serve customers in the European Union area, future research should cover more extensive experts to generalize results globally. In short, we suggest the collection of knowledge inputs from a wider group of 3PLs concerning other customer populations, use cases, and geographical locations [79] (Cao et al., 2018). For this purpose, we conclude this article with the future study of general big-picture studies to widen the narrow research focus connecting all main and subtopics, leaving plenty of room for an additional holistic view. It is already proved that WMS can enhance the perceived value of logistics services, which is a crucial driver of customer loyalty and retention [147]. So, it would be interesting to examine full-fledged research on how 3PL investments in chosen WMSs influence activities using financial metrics analogous to [148] for measuring ERP systems' contribution to firms' performance and extend WMS selection reasoning and justification studies [149].

Lastly, the frontline innovative 3PL operator, especially the CEO, managers, and customer support specialists, validated these research results to pinpoint any missing topics in the literature. With the help of the participation of high-level industry specialists, practically important research area directions were identified to be covered in extant research. The practitioners were able to highlight only a few additions to the findings. Given the literature's answers to the set RQs, we suggest widening the

research of WMSs and 3PL operators, especially in the previously mentioned niche areas. More research with practitioners can be held into the realm of 3PLs and WMSs to address the knowledge shortage in the 3PL and WMS selection intersection; specifically, the practitioners' point of view is barely visible in extant literature and technologies like artificial intelligence [150] for sustainability, are hardly visible in WMS context, at least till now.

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Evaluating low-carbon policy alternatives to support electric vehicle transition: evidence from Bogota-Colombia
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Evaluating low-carbon policy alternatives to support electric vehicle transition: evidence from Bogota-Colombia

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Keywords: electric vehicle, low-carbon policy, energy transition, transport, simulation.
Abstract: The transition from fuel-based vehicles to electric vehicles (EVs) is fundamental in the decarbonisation process of countries – it has become an option to reduce greenhouse gases (GHG). This transition involves transformations of the transport sector that are influenced by transport policy. However, policy makers sometimes experience delays in implementing such a policy, which produces drawbacks in the long-term. The paper aims to assess low-carbon policy alternatives for mitigating the delays in the electric vehicles transition, supported by a simulation model. To simulate, the model uses the historical data of pollution and temperature generated by the Bogota's transport sector in Colombia. Results contribute to understanding the role of low-carbon policy on the reduction of CO_2 emissions in the transport sector. Also, a dynamic perspective shows how the EVs transition in the case of Colombia influences on the desired target policy, such as the Paris Agreement and the intergovernmental panel on climate change (IPCC).

1 Introduction

Nowadays, the nations have taken action about climate change to reduce its effects [1]. Indeed, several countries have adopted the intergovernmental panel on climate change (IPCC) agreement to reduce the increase of global warming to 1.5 ºC [2] as well as the Paris Agreement to reach global temperature below 2 ºC [3-5]. However, these efforts have not yet been sufficient. Previous studies have agreed that, despite these efforts, policy alternatives are needed to support this issue [6-9]. This is corroborated by the emissions growth in several countries [10-12].

In the metropolitan areas of developing countries, the emissions impact is much more significant because of the speed of urbanisation [13]. The urbanisation brings new challenges in terms of transportation and emission reduction, which involve improving the transport policy. For instance, both Mexico and Brazil are among the top 20 emitters with 1.33% of global emissions each, despite adopted transport policy to expand clean transport systems in the last years [14]. In the case of Colombia, the contamination caused by the transport system has not been an essential point on the agenda of policymakers. This situation has brought an increase in the generation of emissions from the transport sector [8,9,15].

Despite Colombia has promoted Sustainable Development Goals – SDGs for protecting the environment, emissions from transportation are still expected to rise in the future [16]. The transport sector has seen a rise in emissions over the last decade. In 2006, 16.2% of all CO_2 emissions were from solid fuel consumption in Colombia and by 2016, its contribution to CO_2 emissions had grown to 23.2% [17], where transport represented 13.5% of this increase [8]. Although electric and hybrid vehicles are less contaminant than gasoline and diesel engines, the diffusion of clean technologies for the transport sector in Colombia has been insufficient.

In this context, this paper assesses the following questions through a simulation model: i) Is it possible to mitigate the CO_2 emission levels with electric vehicle diffusion in Bogota, Colombia until 2050? ii) Could low carbon policies (i.e., Paris agreement or IPCC) foster electric vehicles transition for 2050 in the case of Bogota, Colombia? and iii) What are the impacts of transition delays of electric vehicles on both emissions and temperature in Bogota's transport sector in Colombia?

A low carbon policy for transport system involves identifying the relationship between different categories of transport and their generated emissions [6,18]. Moreover, the policy issue at the regional and national level comprises delays and feedbacks, which could affect the transition processes. Thus, this paper developed a simulation model for understanding dynamics behaviour of the transport system, including different types of technology (e.g. fuel, hybrid, electric vehicle) and the effects of delays in technology transition on the generation of emissions, particularly for electric vehicles.

Several well-known simulation approaches have been used for evaluating transport policy and electric vehicle technology [19,20]. In this sense, system dynamics methodology has offered an excellent fit to evaluate the

transition of the electric vehicle [6,8,19,21,22]. The system dynamics modelling comprises nonlinear dynamics, delays and feedback loops, which are simulated over time [23-25]. Although previous research has used the simulation to analyse causality between low carbon policy and electric vehicle transition [6-8,26,27], there are few studies that address the effects of delay on vehicle technology transition, assessing the low carbon policy targets, especially in the case of Colombia. Thus, a model based on system dynamics simulation was developed to understand the incidence of transition on emissions and temperature.

This paper is structured as follows: Section 2 describes the main background of the research. Section 3 explains the simulation model used for assessing the low carbon policy in Bogota's transport sector in Colombia. Results obtained from the simulation model are presented in Section 4. Finally, the conclusions are presented in Section 5.

2 Background of the research

Due to the increase from 3.4 million vehicles in 2018, mainly determined by private transport demand, the transport sector has become an essential contributor to CO2 emissions in Colombia [10,28]. This situation has provoked resources depletion with a negative impact on the environment as well as public health impacts. Currently, private vehicles produce high emissions at the local level, particularly in Bogotá and Medellin, which has forced the public intervention of policymakers to reduce CO2 emissions [8,16]. A fuel vehicle can emit 256 grams of CO2 per kilometre travelled, while hybrid vehicles generate 85 grams, that is 67% less; as for a hybrid electric plug-in vehicle, it emits 43 grams, 83% less; and an electric vehicle, zero-emissions [29].

The electric vehicles have a significant impact on the process of decarburisation of the environment [11,30]. However, the electric vehicles transition for passengers' transportation requires the construction of new infrastructure [31-33]. Inside the process of transition from fuel vehicles to electric vehicles, there is evidence of the increase of innovation processes [34]. Proof of this is that some countries such as Germany, Sweden, Brazil and China have incorporated scheme for development of electric vehicles industry, generating innovation and changes on conventional energy systems [32,35,36].

Over recent years, several strategies have been developed to support electric vehicle transition [6,37-39]. The research on electric vehicles transitions have been addressed from different aspects. First, studies that associate passenger flows to determine transport capacity and demand [40-42]. Second, studies that assess the electric vehicles diffusion and its impact on the environment [11]. Third, studies related to analyse the transport congestion [43]. This paper contributes to analysing the delays of the electric vehicle transition in the case of Bogota city and their effects on the policy targets of emissions reduction.

The transition of the fuel vehicle to the electric vehicle could be understood around different modelling approaches [27,44]. In this paper, the system dynamics modelling is proposed to represent the interaction between delays of the electric vehicles transition and its effects on the environment (i.e., CO2 emissions and temperature). System dynamics is an approach based on the feedback control theory used to analyse complex system [6,45-47]. As the transport system involves complex relationships, the traditional approaches (e.g., optimisation approach) are not suitable to understand the delays of the system and their effects in the long term [9,19,48,49]. By utilizing a system dynamics model, a comprehensive system-based view of transport planning can be achieved, and this can be utilized to show decision-makers the importance of these feedbacks and lagged responses [19]. Thus, system dynamics has been applied in this paper. The paper describes the model's dynamics, as well as providing a brief explanation of the mathematical model used.

3 Methodology and model description

A simulation model was built on understanding the dynamics of the delays of electric vehicles transition and their effects on the CO2 emissions and temperature. The proposed model was developed as a stock and flows diagram, including three interconnected sections. In the first section, the model comprises the private and public vehicles according to the different types (i.e. gasoline, diesel, electric vehicle). The second section represents the dynamic of the accumulated emissions generated by fossil fuel vehicles. The third section shows the changes in temperature. Details on the sections of the simulation can be observed in Figure 1.

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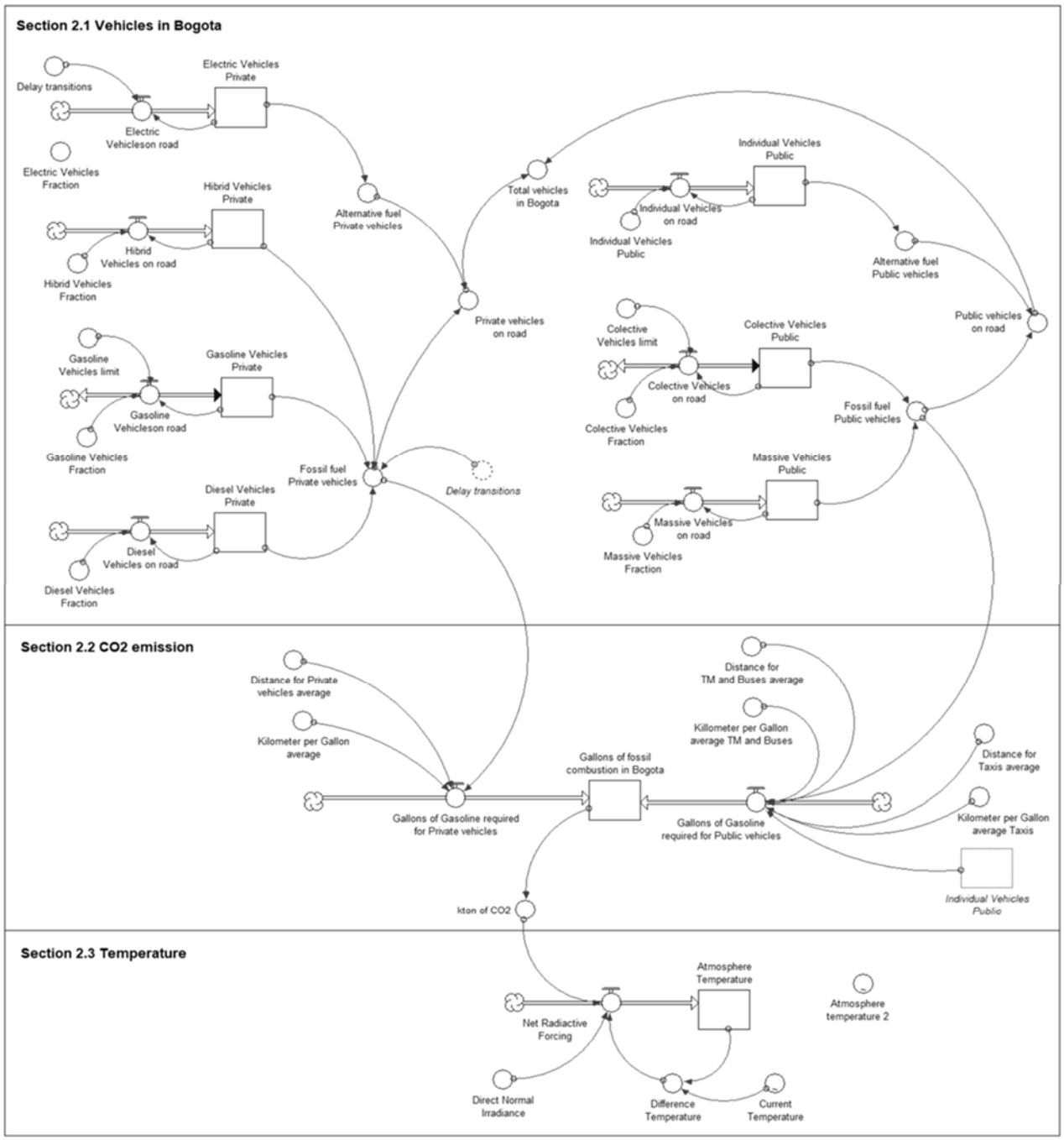

Figure 1 Simulation model for the case of study of Bogota City

The stock-and-flow diagram is composed of a system of differential equations, which is solved through a simulation structure. For instance, in section 2.1 – vehicles in Bogota – the accumulated electric vehicles private (EVp) (1) and electric vehicles on road (evr) (2) was calculated by Equation 1 and 2, respectively. A brief explanation of the model structure is presented below.

$$EVp\,(t) = EVp(t-1) + \int evr(t)\,(dt) \qquad (1)$$

$$evr\,(t) = EVp(t-\varphi) \qquad (2)$$

Where,

φ: is the constant delay time.

3.1 Total vehicles in Bogota

The vehicles are classified according to the type of service as private, official, public transportation and diplomatic, as illustrated in Figure 2. Besides, public transportation by type of service can be individual,

collective and mass transit. The data was taken of the transport secretary of Bogota [50] according to the type of technology (i.e. gasoline, diesel, hybrid and electric vehicles) for private and public transportation.

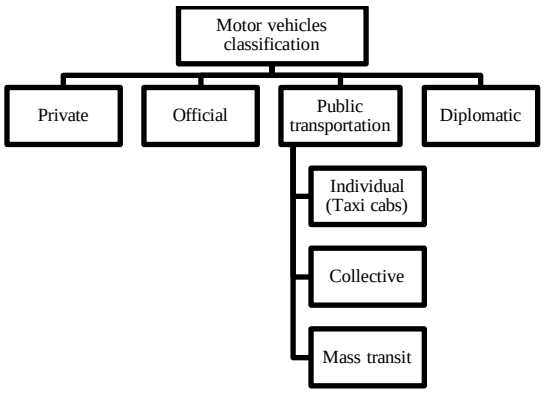

Figure 2 Vehicles classification in the Bogota city
Source: Adapted from Secretaria Distrital de Bogota [50]

3.2 CO_2 emissions

The CO2 emissions are calculated as from the gallon of gasoline and diesel – 8,887 grams CO2 per gallon for gasoline and 10,180 grams of CO2 for diesel [51]. The gallon consumed per fuel vehicles is the average between gallon per kilometre and distance travelled. For private fuel vehicles, it is estimated 40 kilometres per gallon [km/gal] and 30 kilometre per day [km/day] [52]. On the one hand, public fuel vehicles reach an average of 45.8 [km/gal] for taxis [53], while for collective and mass transit is 6.36 [km/gal] [54]. On the other hand, the distance travelled per day of one taxis is 232 [km] [53], and 300 [km] for collective and mass transit [54]. An initial value of CO2 equivalent was taken from ground transportation of 4745 kilotons by 2012 [55].

3.3 Temperature section

This sector was adapted from Fiddaman's model for analysing the temperature, as illustrated in Figure 3 [56]. The variables used to calculate the atmosphere temperature are: i) previous CO2 emission, ii) direct normal irradiance, and iii) the net radiative forcing. The direct normal irradiance – DNI – for Bogota used in the model was 1177 kWh/m2 per year [57]. The net radiative (F) (3) forcing to CO2 is calculated from Equation 3 [58].

$$F = 5.32\, ln\left(\frac{C}{C_o}\right) + 0.39\left[ln\left(\frac{C}{C_o}\right)\right]^2 \qquad (3)$$

Where C represents the concentration of CO_2, while C_0 is equal to 278×10^{-6}.

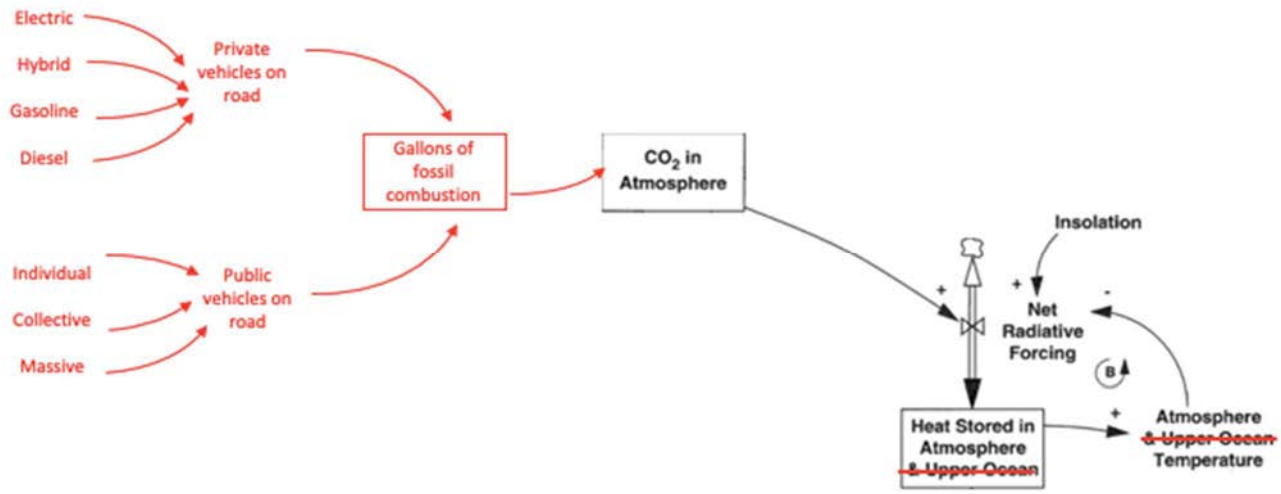

Figure 3 Temperature sector adapted from Fiddeman's model

3.4 Model validation

The simulation model developed was extensively validated. This research applied tests of consistency and dimensionality suggested by [59-61]. Experts confirm the dimensions of the simulation model through checking based on previous studies [6,7,15]. Figure 4 presents a model behaviour test for the actual CO2 emission levels data – reference mode – and simulated data from 2000 to 2017. It can be seen that both levels of CO2 have the same trend (red line). Thus, the simulation model passes the behaviour validation test for carrying out the following scenarios of simulation.

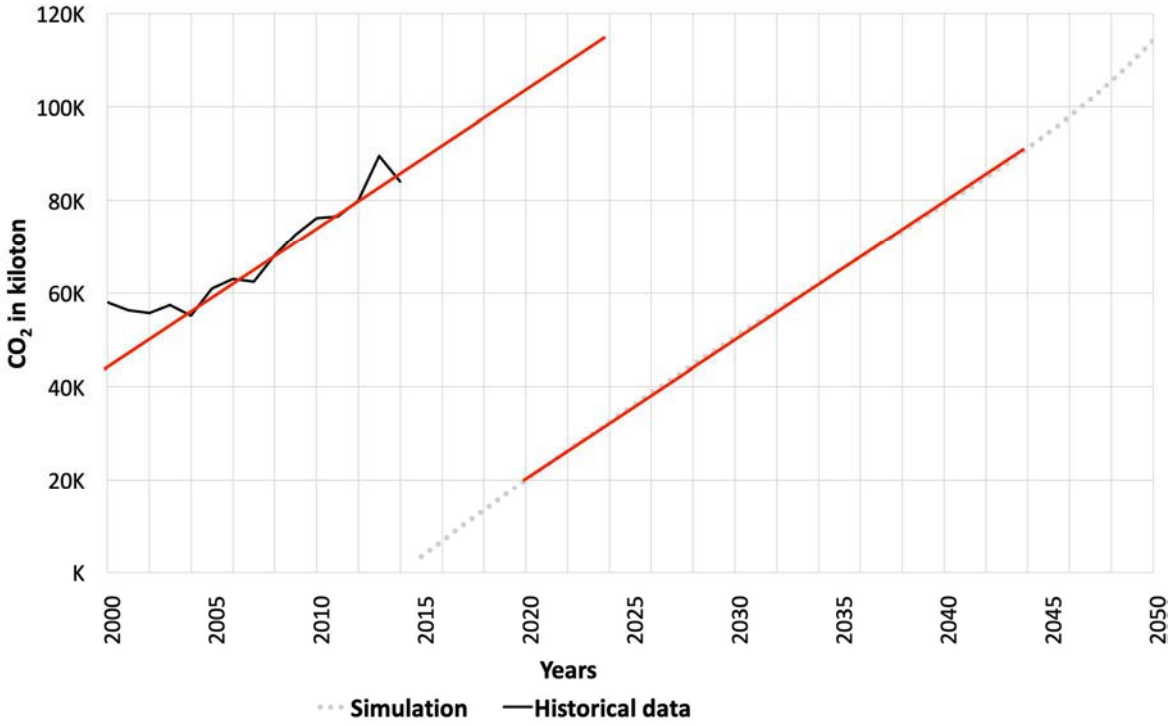

Figure 4 Model behaviour tests for CO_2 emission levels of Bogota

3.5 Simulation scenarios

We simulated the model within four scenarios. These scenarios represent the delays in years of EVs transition in the next years by Bogotá, as shown in Figure 5. The first scenario represents current conditions – business as usual (BAU). There are no incentives or stimulates to gain EVs in this scenario. The acquisition of the EVs continues with a lower increase like up to now. This scenario does not consider any of the environmental agreements such as Paris agreement – limit global warming to 2.0 ºC – or IPCC – limit global warming to 1.5 ºC. The second scenario considers 15 years for electric vehicles transition, namely the incentives for the acquisition of EVs will be after 15 years. Delaying electric vehicles transition could generate uncertainty for infrastructure development in the short term. Insufficient infrastructure for attending new alternatives transportation produces congestion problems. The third scenario considers a delay of 10 years for the transition of clean technology alternatives. This scenario represents a transition not far so long to develop infrastructure and incentives to foster EVs acquisition, searching to align with the global environmental policy, such as Paris agreement and IPCC. The fourth scenario considers encouraging the transition to acquire EVs within the next 5 years. This scenario shows a positive development in infrastructure and tax reduction to the incentive in the acquisition of EVs. The concept to invest in EVs will help to reduce the CO_2 emission levels.

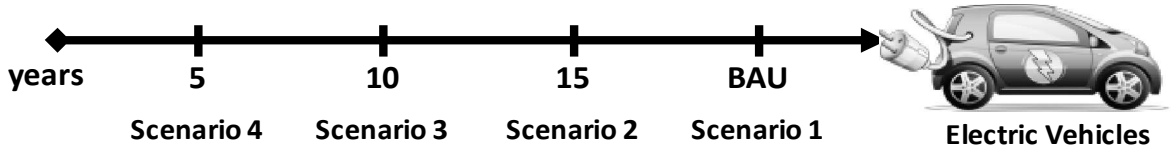

Figure 5 Proposed scenarios to assess the EVs transition

In summary, the scenarios focus on the low carbon policy proposed in Table 1. These policies allow assessing the trend of the temperature and CO2 emission levels between 2018 and 2050 according to the transition to EVs.

Table 1 Low carbon policy proposed

Scenario	Description	Equation within the simulation model	Alternatives of low carbon policy for the EVs transition (φ)
1	Business as usual – BAU	$evr\ (t) = EVp(t-\varphi)$	-
2	Uncertainty for infrastructure development		15
3	Searching to align with the worldwide environmental policy		10
4	Optimistic development in infrastructure and tax reduction to the incentive in the acquisition of EVs		5

4 Results

4.1 Electric vehicle transition

Private EVs have an exponential increase in the four scenarios, as illustrated in Figure 6. Scenarios 2, 3 and 4 show an increase of 1.5 million EVs for every 5 years of transition, while the scenario 1 shows a reduction of 5.5 million EVs for the year 2050 due to the delays for the EVs transition in Bogota. Although these results are similar to the results obtained by Ospina et al. [7] and Herrera et al. [6] in terms of the growth of private electric vehicles in Bogota, our results consider the targets of the environmental policy of the Paris agreements and IPCC. The fragmentation between the design and implementation policy caused by the transition delays produces effects on temperature and emission reduction in the long-term.

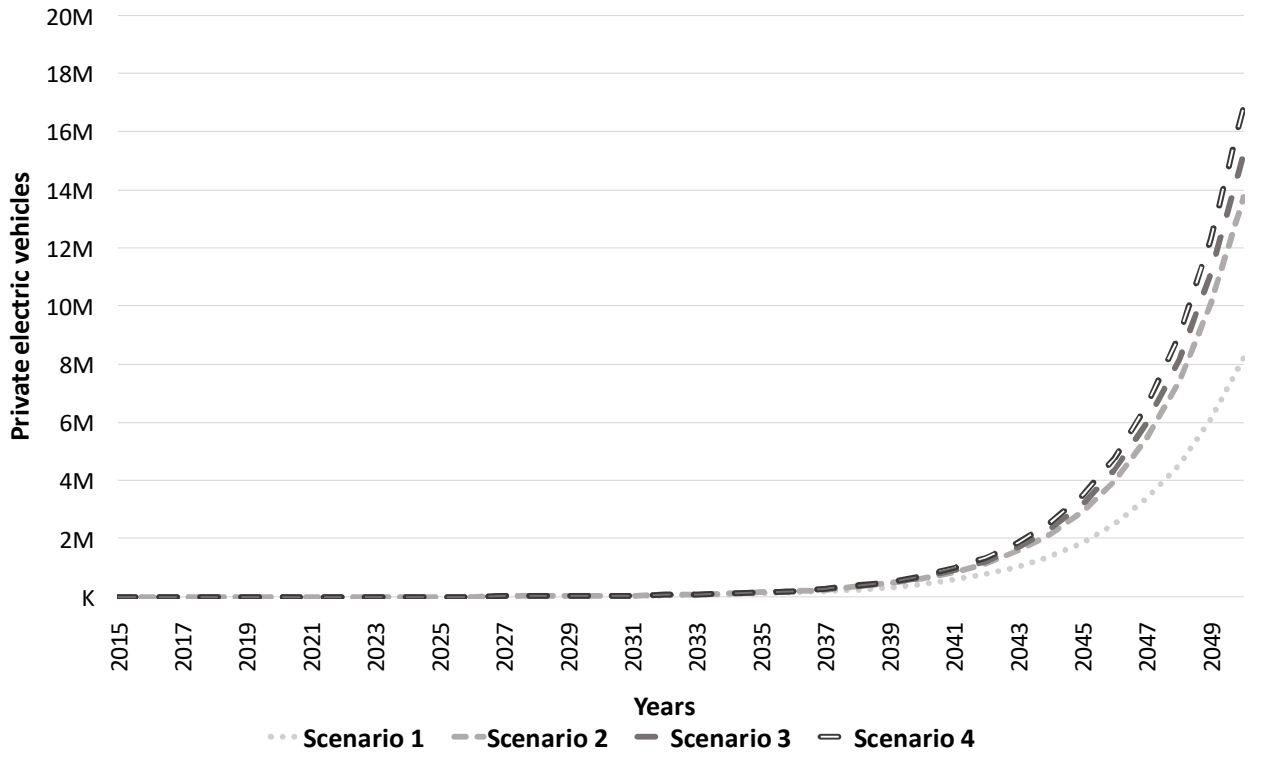

Figure 6 Private electric vehicles trend until 2050 in Bogota

The simulation shows that scenarios 3 and 4 increase amount of EVs compared with BAU scenario by 2050, as presented in Table 2. These results show how an increase in EVs as from investment has a positive impact on transportation, while the lack of EVs diffusion and financial resources could affect the transportation system.

Table 2 Electric vehicles transition by 2050

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
EVs for 2050 in million	8.2	13.7	15.2	16.8

4.2 CO_2 emission levels

The trend of CO2 emission levels for the next 30 years is represented in Figure 7. This behaviour is associated with the EVs dissemination in Colombia according to the proposed scenarios (Table 1). The percentage from 2012 to 2050 for the four scenarios are: the first scenario is 24.8%, the second scenario is 9.3%, the third scenario is 6.4%, and the fourth scenario is 3.4%. Results show that the increase in the CO2 emission levels for all scenarios is very high. Scenario 1 represents the highest increase, while scenario 4 represents the lowest increase for the CO2 emission levels. On the one hand, these results disagree with Ospina et al. [7]; however, both studies show the need for an environmental policy for the case of Bogota city. On the other hand, the results under the BAU scenario coincide with the increase between 2030 and 2050 reported by Espinosa et al. [7] BAU scenario by 2050 shows an increase of 24.8% in the CO2 emission levels. This trend is directly associated with the traditional use of fossil fuel in the city [15]. As different delays can occur in Colombia, it may affect the EVs diffusion. Thus, the CO_2 emissions can increase in all scenarios because of a higher dependence on fossil fuel and gas. Other studies also agree a higher dependence on fossil fuel does not allow to reduce the emissions [6,7].

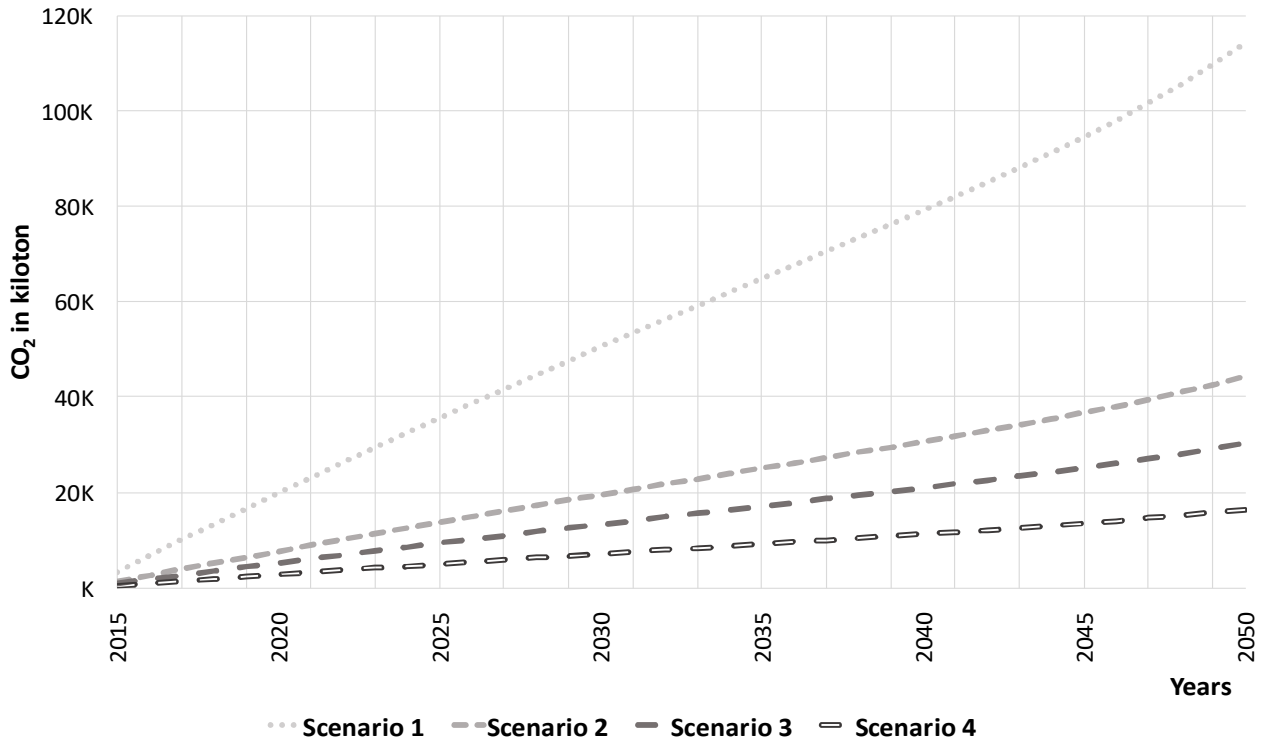

Figure 7 CO2 emission levels trend until 2050 in Bogota

Table 3 shows the CO2 emission levels by 2050 for each of the scenarios. The fourth scenario shows a decrease in CO2 emission levels due to a reduction of fuel vehicles. This situation might achieve with policy alternatives focus to foster clean technologies; however, the complementarity with other policies (e.g., energy policy and transport policy) should be considered.

Table 3 CO2 emission levels by 2050

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
CO_2 emission for 2050 in kilotons	114,266	44,392	30,417	16,442

4.3 Temperature variation

An analysis of the behaviour of temperature for future years is presented in Figure 8. Both the CO2 emission levels, and the temperature suffer the highest increase for the next years (see, Figure 7 and 8). The first scenario shows an increase of 2.09 ºC for the temperature more than the fourth scenario that presents the lowest increase for the temperature with an increase of 1.72 ºC.

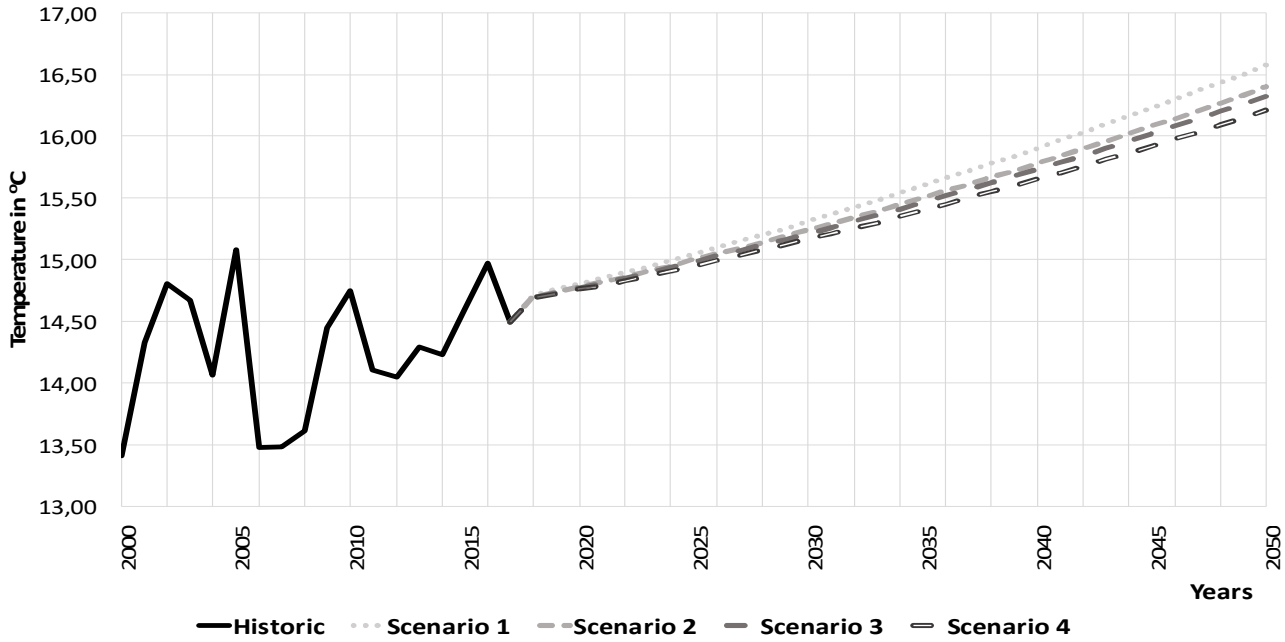

Figure 8 Temperature trend until 2050 in Bogota

Table 4 presents the temperature for each of the proposed scenarios by 2050. For achieve the reduction of the temperature through electric vehicles transition, it is necessary to foster a positive interaction between private industry and government.

Table 4 Temperature variation by 2050

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Temperature by 2050 (Cº)	16.58	16.40	16.32	16.21

Although the scenarios do reduce emissions, the results show that it is insufficient in comparison with the goal of the Paris Agreement and IPCC, as illustrated in Figure 9. The difference in temperature for the four scenarios in comparison to the temperature mean for Bogotá are: the first scenario is 2.09 ºC, the second scenario is 1.91 ºC, the third scenario is 1.83 ºC, and the fourth scenario is 1.72 ºC.

Results show that none of the four scenarios meets the IPCC criteria to limit the increase of 1.5 ºC global warming. The fourth scenario exceeds the IPCC criteria in 0.22 ºC; however, scenario 4 has less difference value in comparison to the other scenarios. The first scenario exceeds 0.59 ºC, the second scenario exceeds 0.41 ºC, and the third scenario exceeds 0.33 ºC. The Paris agreement criteria limit the increase to 2 ºC above the actual mean temperature is fitted by the scenarios 2, 3 and 4. The first scenario shows that it exceeds 0.09 ºC.

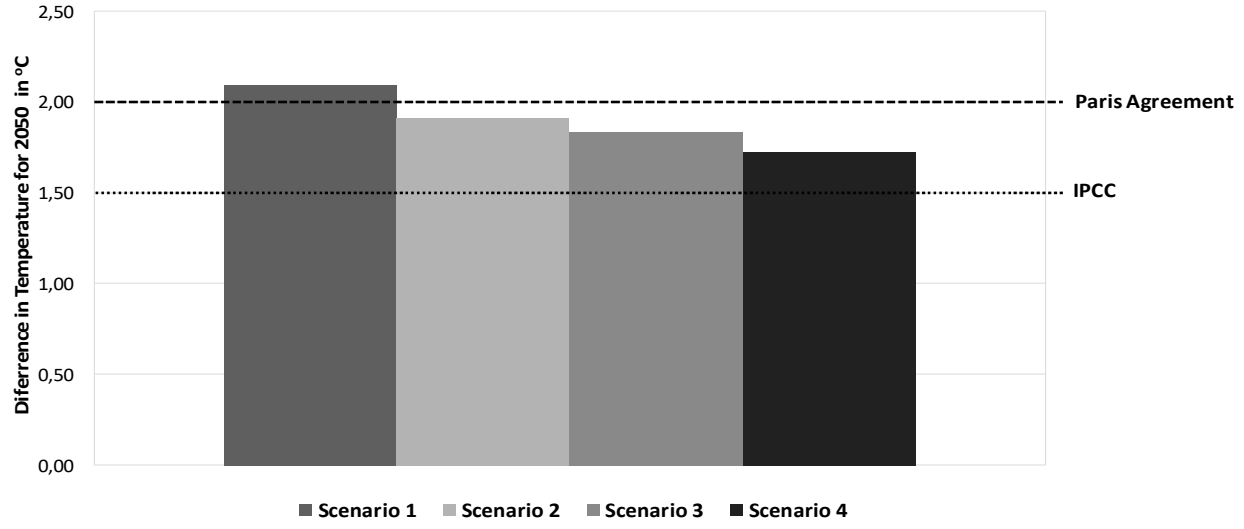

Figure 9 Difference in temperature by 2050

5 Conclusion

This paper has explored scenarios for the electric vehicle transition in the case of Bogotá, Colombia. Results show several lessons for understanding the long-term effects of delays in EVs diffusion for developing countries.

First, it is not sufficient to incentive the acquisition of EVs to reduce the CO2 emission levels. Similar to that reported for other countries [6,62], the subsidies are only beneficial in the earlier year of market introduction and should cover the infrastructure for these clean technologies [6,63,64]. Also, the GHG mitigation in the case of study addressed should include the reorganisation of the transport system: programs to retire old vehicles, better use of the capacity both vehicles and bicycle and intermodal options [10,16,31,65]. Thus, it is urgent to take action to reduce gasoline and diesel engines on private and public vehicles sector.

Second, the results suggest a strong challenge for the mitigation of an environmental issue that allows reaching the targets of the Paris Agreement and IPCC in terms of the EVs transition. Although Bogotá's efforts concerning the accessibility of transportation programs have been the highlight [66], the low carbon policy and its effects in the long-term has not sufficiently discussed.

Third, the paper reflects on the environmental concerns related to the transport system, described as the delays in the EVs transition that affect the targets of the Paris Agreement and the IPCC. In this regard, the paper proposes an intervention systemic for the design of low carbon policy in the case of Bogotá and other developing countries of Latin America.

Although the incentives for the EVs transition are one of the most crucial issues to the diffusion of the clean technology [21,27,67], this paper contributes to assessing the delays as an essential aspect within transport policy design. Considering the delays in the EVs transition could mitigate problems of fragmentation between the design policy and implementation.

The case of Bogota shows that the delayed diffusion of the EVs could affect the targets of the Paris Agreement and IPCC. In this regard, the paper proposes the development in infrastructure and tax reduction to the incentive in the acquisition of EVs over the following five years.

The results suggest prosperous areas for empirical work, which include the modelling – for instance, the analysis of the installed capacity of energy for attending the EVs transition in the case of other cities in Latin America.

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Ordinal regression analysis of traffic collision accidents in Jordan 2021: factors and severity assessment

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Keywords: collision, injuries, ordinal, factors, severity.
Abstract: One of the significant challenges that the world is confronting is road traffic accidents. The aim of this study is to determine the key factors contributing to traffic collision accidents and to utilize an ordinal regression model to identify the factors that contribute to accident severity. This will be achieved by fitting a suitable equation based on a dataset obtained from the Traffic Institute's database for the year 2021. The findings from the ordinal logistic regression analyses indicate that weather conditions, road surface, speed limit and illumination levels are significant factors that contribute to the severity of crashes with p-values of 0.003, 0.085, 0.025 and .002 respectively. Hour of the day, day of the week, week and governorate are insignificant in collision accidents in Jordan in 2021. In this comprehensive study on traffic collision accidents in Jordan during 2021, our analysis has revealed some significant findings. Our data indicates that the peak period for traffic collision accidents was between 18:00 to 18:59, and Thursday was found to have the highest number of incidents. In terms of the month, July recorded the highest number of accidents. It was also noted that Amman had the largest share of accidents. These findings highlight the need for increased awareness and stricter enforcement of traffic regulations during peak periods and in high-risk areas.

1 Introduction

The prevalence of traffic accidents and their resulting fatalities, injuries, and associated social and economic impacts represent a major challenge for nations worldwide. Collision accidents are defined as incidents involving the interaction of two or more vehicles and their drivers, caused by factors such as violation of traffic regulations, failure to yield, driver distraction, and driver fatigue. In 2021, approximately 1 million car accidents took place in Jordan, leading to 589 fatalities resulting solely from collision accidents [1].

As a result of the surrounding circumstances, Jordan has experienced a significant increase in population and vehicles, leading to a discrepancy in traffic accident rates despite preventive and remedial measures taken by public security departments.

A quick look at the results of road accidents in Jordan in 2021 shows that 160,600 accidents occurred, of which 11,241 were serious, resulting in 589 fatalities and 737 severe injuries, 6,325 moderate injuries, and 10,423 minor injuries, with a monetary cost estimated at 320 million Jordanian Dinars [1].

The study aims to identify the key factors that contribute to traffic collision accidents across various governorates in Jordan and their relationship with the level of injury severity.

To achieve the study's aim, a comprehensive analysis of traffic collision accidents in Jordan was conducted. The study analyzed data from the Jordanian Traffic Institute's database on collision accidents that occurred in 2021. The sample consisted of all recorded collision accidents across various governorates in Jordan during the study period, and the data included information on the date, time, location, and severity of the accidents, as well as the factors that contributed to them. To analyze the data, descriptive statistics were used to identify the frequency and distribution of collision accidents by time of day, weather conditions, and other factors. Additionally, logistic regression analysis was used to identify the factors that were significantly associated with the severity of injuries sustained in the accidents.

Overall, this study provides a comprehensive analysis of traffic collision accidents in Jordan and identifies key factors that contribute to their occurrence and severity. The findings of this study can inform the development of targeted interventions and policies aimed at reducing the incidence and severity of traffic collision accidents in Jordan.

2 Literature review

Extensive research has been carried out to determine the foremost factors that lead to different accident types, such as collision accidents. Han [2] conducted a study utilizing a black box camera mounted within vehicles to assess the level of damage and circumstances surrounding traffic collisions. He discovered a cost-effective method for predicting and preventing collision accidents, a finding that represents an improvement over traditional approaches. Didin et al. [3] studied previous studies focused on rear-end collisions as a try to concentrate on the

main risk factors that affect crash accidents. They found that there were many factors that led to rear-end collisions, such as: the behaviour of driving, retarding and acceleration, headway time and collision time. Han [4] presented a new approach to make a full analysis of a collision between vehicles. The approach was introduced because of the difficulty of gathering accurate information. As a result, the method used a vector as a main factor to define many relevant factors, such as the direction and speed of a vehicle, and then present qualitative calculations. A. Rakhonde et al. [5] presented a new smart vehicle system to detect collision accidents and monitor pollution. They found that the response time for medical cars was reduced while the sensors were installed on the tires and they were able to alarm for the collision crash in different directions. Yang et al. [6] designed a new algorithm to detect vehicle collisions during driving based on using Android installed on smartphones. The procedure was to send all the information to the preset mobile number when the collision is detected and the camera starts work by taking an instant photo and sending it to the number. Darwish [7] investigated the factors that influence a driver's decision to either stop at intersections or continue driving without stopping. Results showed 48% of drivers stopped completely, with female drivers and bus drivers stopping more often. Driver age and compliance with stop signs were directly proportional. Cheng et al. [8] used statistical analysis to construct discrete choice models to investigate the impact of multiple factors on crash severity on a freeway in China. Based on 1154 accidents, the study found 11 significant factors affecting crash severity, including driver gender and age, vehicle type, road conditions, and lighting. The results can be used to develop targeted proposals for improving traffic management. Prajongkhaa et al. [9] investigated the causes of injuries and deaths resulting from motorcycle rear-end collisions and analyzed factors contributing to their severity level in Thailand. The study found that perception failure was the primary contributing factor and that collisions with parked vehicles resulted in higher probabilities of death. The findings can be used to develop policies and countermeasures to prevent and reduce the severity of MC rear-end crashes. Yang et al. [10] utilized data from the Chinese National Automobile Accident In-Depth Investigation System to develop a prediction model for traffic accident severity. Using random forest, they identified seven important accident features, including four new features not previously ranked. The optimized model resulted in higher accuracy for predicting traffic accident severity. Infante et al. [11] analyzed daily road traffic accident (RTA) data from 2016 to 2019 in a district of Portugal to identify the determinants of the type of RTA (collision, crash, or pedestrian running-over). The study found that geographical, meteorological, time of day, driver and vehicle characteristics, and road characteristics were significant determinants. The authors compared several machine learning algorithms, and found that combining these with ROSE for class balancing improved their performance, with random forest performing the best. Li et al. [12] aimed to predict the severity of traffic accidents on mountain freeways using machine learning algorithms. Four models were constructed using SVM, DTC, Ada_SVM and Ada_DTC, and RF was used for feature selection. Rainfall intensity, collision type, number of vehicles involved and road section type were found to be important variables. The combination of Ada_SVM and RF achieved the best prediction performance, with 78.9% and 88.4% prediction precision and accuracy, respectively.

3 Methodology

Data on road traffic accidents that occurred between January and December 2021 were gathered from the traffic institute, which, among its various responsibilities, keeps records of all accidents and crash-related information, including the degree of injuries sustained and property damage. These statistics are published annually in both soft and hard copies.

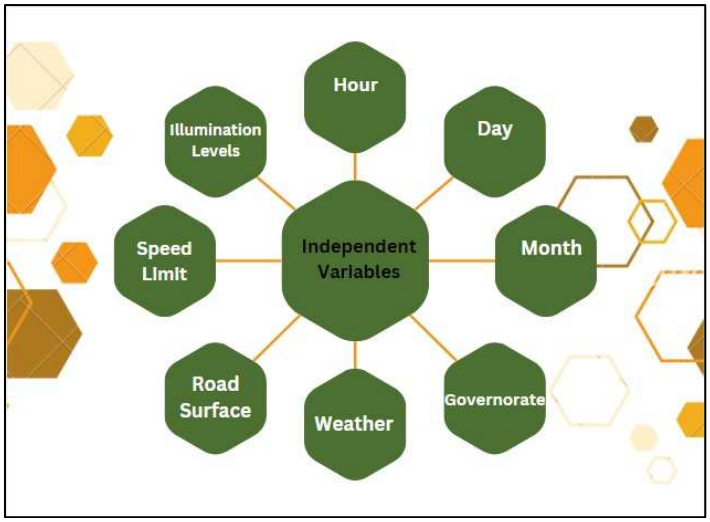

Figure 1 Independent variables

Ordinal regression analysis of traffic collision accidents in Jordan 2021: factors and severity assessment

Walaa Darwish, Haneen H. Darwish

This comprehensive study encompasses all governorates in Jordan, divided into twelve distinct segments. Several critical variables will be meticulously analyzed, including the hour of the day, day of the week, monthly trends, governorate location, weather conditions, road surface state, speed limit, and illumination levels (Figure 1).

Hourly recordings of the time of day were meticulously gathered, as well as daily recordings of the day of the week, covering a comprehensive range from Saturday to Friday. All twelve governorates and twelve months were meticulously included in the study.

The weather conditions were thoroughly evaluated and divided into six categories, including clear sky, high winds, frosty, foggy, dusty, and rainy. The road surface conditions were meticulously analyzed and sorted into seven unique categories, including arid, frosty, glacier, sandy, oily, clayey, and muddy. The speed limit was further divided into nine distinct groups, while the illumination level was categorized into six separate types.

Following data collection, statistical analysis was performed on the exported data using SPSS. The severity level of accidents is the dependent variable in this study and has been classified into four distinct categories: 1-Fatal, 2-Severe, 3-Moderate, and 4-Minor (Figure 2).

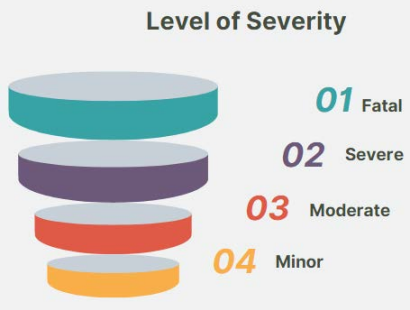

Figure 2 Types of level of severity

4 Result and discussion

4.1 Hour of the day

A thorough 24-hour analysis was conducted to determine the precise time frame in which collision accidents exhibited the highest frequency of occurrence**.** Data analysis revealed that the hour ranging from 18:00 to 18:59 had the highest incidence of collision occurrences (Figure 3). Numerous factors may account for the elevated rate of accidents during the 18:00 to 18:59 hour period. Some of the potential contributing elements include are that the 18:00 hour is often marked by peak hour traffic as individuals return home from work or school. This increase in traffic volume on roadways raises the risk of accidents. Additionally, decreased visibility during the setting sun at this time may also contribute to an elevated risk of collisions. Furthermore, driver fatigue is another factor to consider. Individuals who have been driving for prolonged periods during the day may experience fatigue and decreased levels of alertness in the evening, contributing to a heightened risk of accidents.

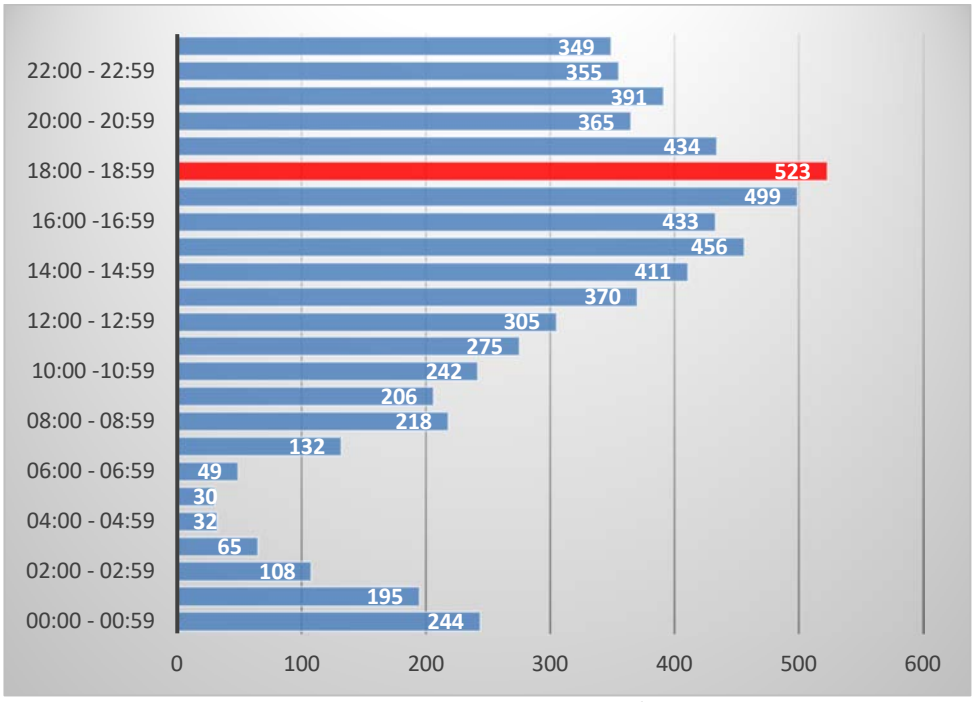

Figure 3 Collision accidents vs. hour of the day

Ordinal regression analysis of traffic collision accidents in Jordan 2021: factors and severity assessment

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4.2 Day of the week

An in-depth analysis was conducted by incorporating all days in the examination, with the purpose of uncovering the critical day. The results of the study indicated that Thursday had the highest frequency of collision accidents, with 1137 incidents recorded (Figure 4). A major contributing factor to the elevated frequency of collision accidents on Thursday may be attributed to the increased rush hour traffic during the evening hours. With Thursday being considered the terminal day of the workweek, a substantial number of commuters strive to leave work and return home in preparation for the weekend. This results in congested roadways and heightened traffic volume, which can increase the likelihood of collisions. Furthermore, the extended travel times associated with increased traffic on Thursday may lead to increased driver frustration and potentially reckless driving behaviour, further exacerbating the situation and contributing to the higher frequency of collision accidents.

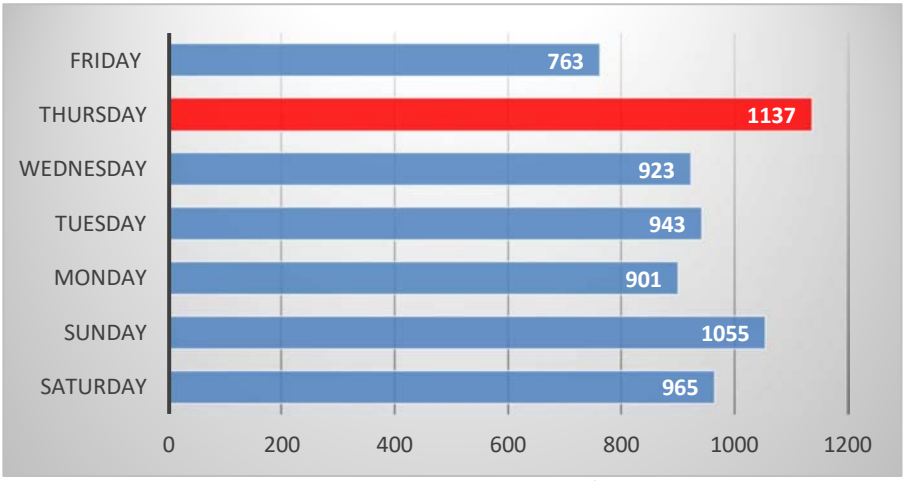

Figure 4 Collision accidents vs. day of the week

4.3 Monthly trends

The results of the study, which were derived from a thorough examination of collision accidents over a one-year period, indicated that July was the month with the highest frequency of collision accidents reported (Figure 5). The higher frequency of collision accidents in July can be attributed to several factors. One potential explanation is the increased influx of returning expatriates, particularly from neighboring countries such as Saudi Arabia and Kuwait, using their vehicles, which results in an increase in traffic volume and congested roadways.

Another possible explanation for the increased frequency of collision accidents in July is the presence of various holidays and festive events in Jordan. The summer season often sees an increase in road trips, family vacations, and other travel activities, which can lead to higher traffic volume and a higher likelihood of collisions.

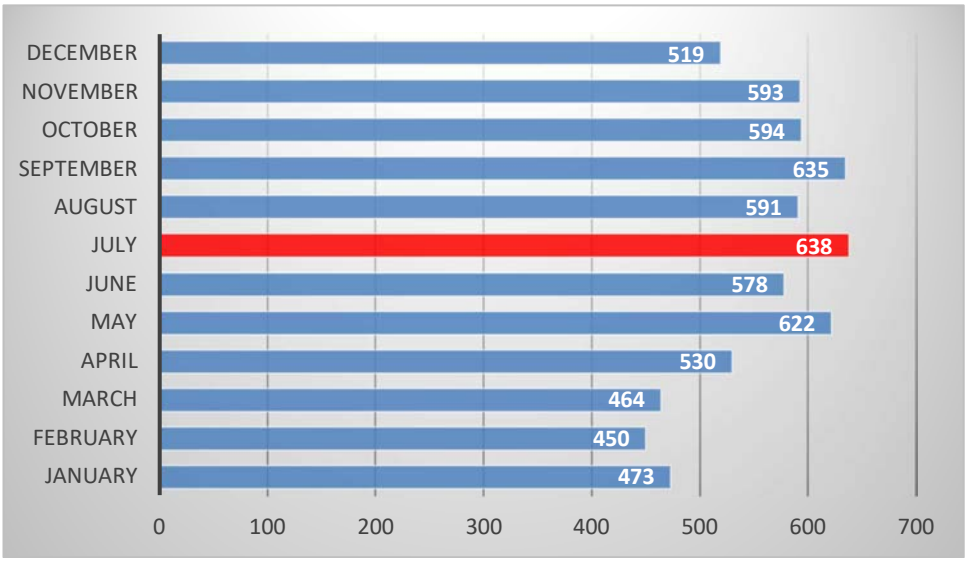

Figure 5 Collision accidents vs. month of the year

Ordinal regression analysis of traffic collision accidents in Jordan 2021: factors and severity assessment

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4.4 Governorate location

The higher number of collision accidents recorded in the capital city of Amman (2842 accidents, Figure 6) may be due to a variety of factors. One possible explanation is the higher population density in Amman estimated to be over 4 million in 2021 * which leads to increased traffic volume and a greater likelihood of collisions. Additionally, the presence of a complex road network in Amman, with a large number of intersections, overpasses, and underpasses, could increase the likelihood of collision incidents and contribute to the higher number of recorded accidents in the city. Furthermore, the city's status as the political and economic center of Jordan could also result in higher levels of vehicular traffic.

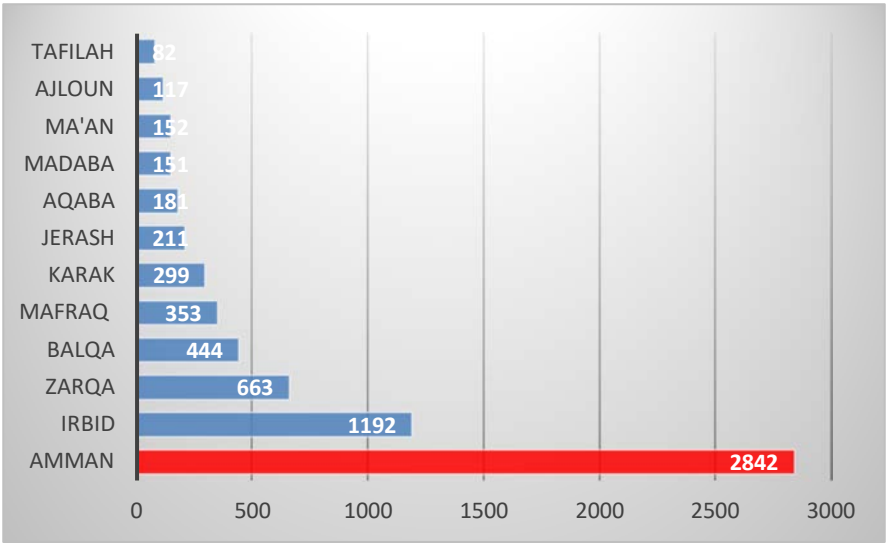

Figure 6 Collision accidents vs. governorate

4.5 Weather conditions

The data analysis revealed a clear trend, with the highest frequency of collision accidents being recorded in clear sky weather conditions, representing a staggering 96.5% of the total accidents observed in the study(Figure 7). The contributing factors behind this trend can be attributed to several key mechanisms. Firstly, increased visibility under clear sky conditions is known to facilitate high-speed and aggressive driving. Secondly, drivers may experience a false sense of security in clear weather, leading to decreased attention levels and elevated risk-taking behavior. Finally, glare from the sun in clear weather conditions can significantly impair drivers' visibility and increase the risk of collision accidents.

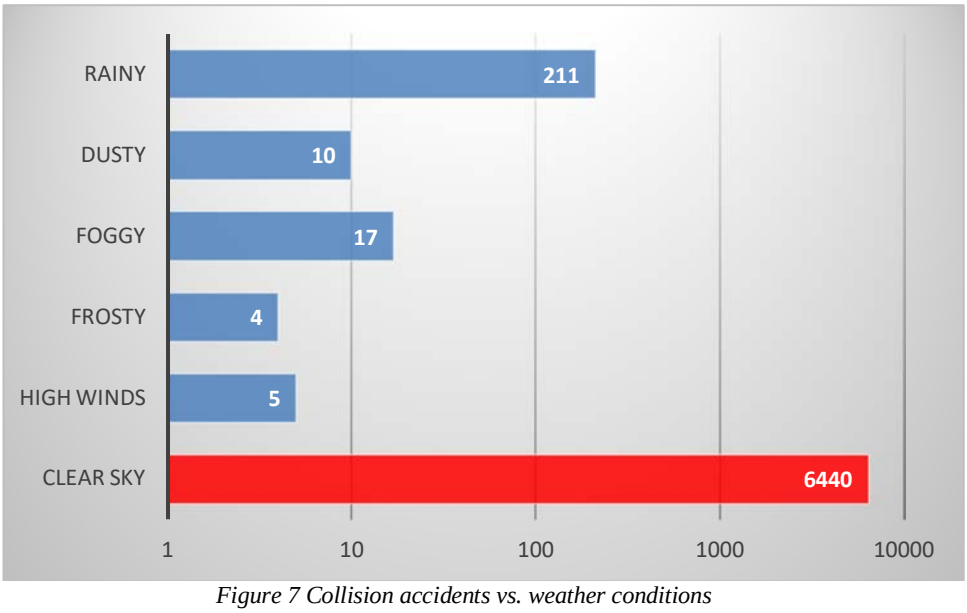

Figure 7 Collision accidents vs. weather conditions

4.6 Road surface state

It was noted that when the road surface is arid the number of collision accident is recored as a high level with a percentage of 96% (Figure 8). This phenomenon could be attributed to the notion that drivers tend to feel a false sense of comfort and security when driving on arid road surfaces. The absence of visible road hazards, such as oil or other slippery substances, can result in drivers adopting higher speeds and more aggressive driving behaviors.

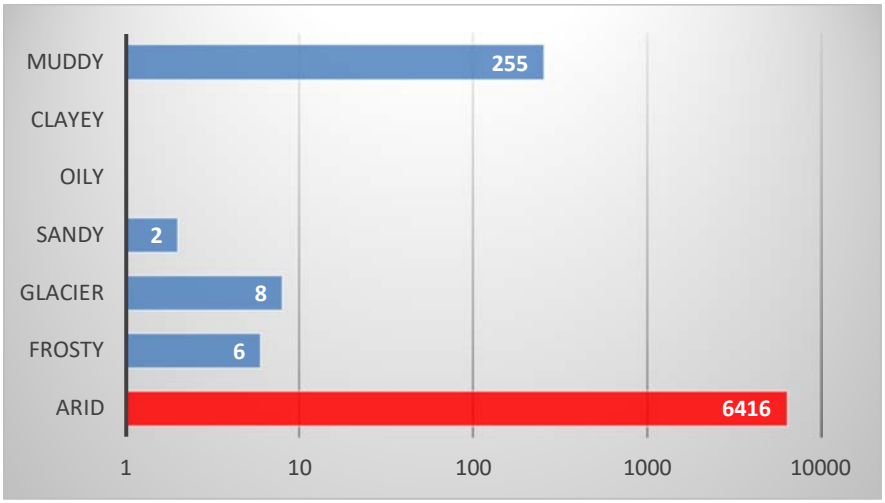

Figure 8 Collision accidents vs. road surface state

4.7 Speed limit

The observation that roads with a speed limit of 60 km/hr recorded the highest incidence of collision accidents among the 9 categories of speed limits, with a rate of 35% (Figure 9), is particularly noteworthy. The reason why the highest incidence of collision accidents was recorded for roads with a speed limit of 60 km/hr, and not higher or lower speeds, could be due to several factors. Firstly, roads with a speed limit of 60 km/hr are often found in urban areas where there is a high volume of traffic and complex road networks, which can increase the risk of collisions. Secondly, the speed limit of 60 km/hr may not accurately reflect the typical driving speeds on these roads, leading to an increased risk of collision as drivers may be traveling at speeds that are either too fast or too slow for the conditions.

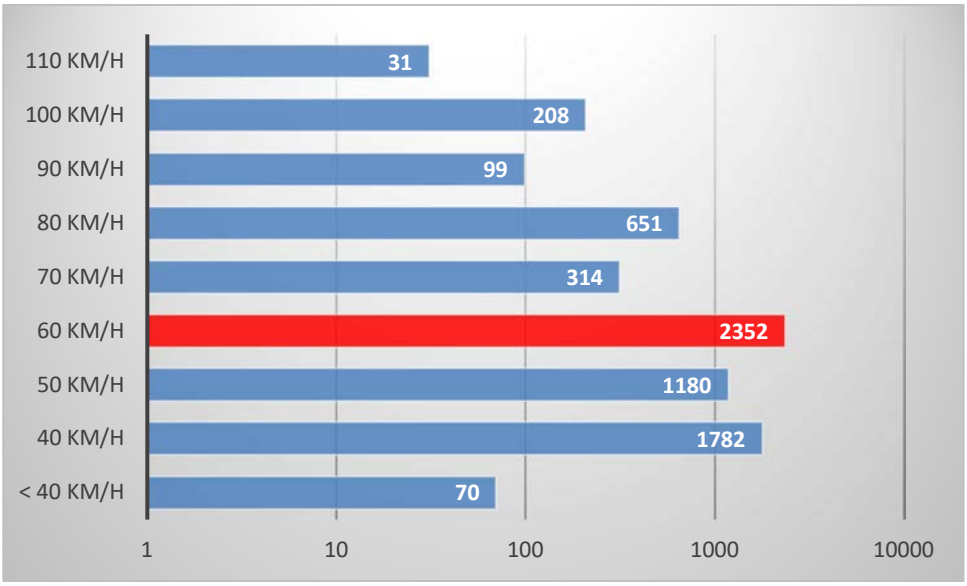

Figure 9 Collision accidents vs. speed limit

4.8 Illumination levels

It was established that, among the various illumination levels, daytime was recorded as the most prevalent, accounting for 58.7% of all recorded events (Figure 10). The elevated risk of collision accidents can be attributed to several factors. One major contributor is the increased

volume of traffic during daylight hours as compared to other levels of illumination. This results in a greater number of vehicles on the road and a higher probability of vehicle interactions, thus creating more opportunities for collisions to occur.

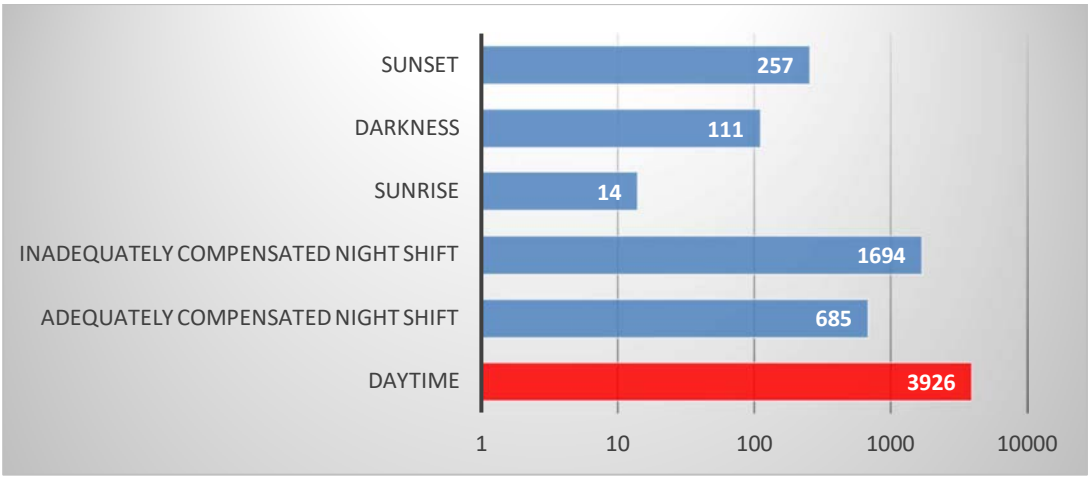

Figure 10 Collision accidents vs. illumination levels

4.9 Statistical analysis

For the purpose of this research, the statistical analysis was conducted using SPSS ver. 22. The initial data was extracted from the traffic institute and documented in an Excel sheet. However, before importing the data into the software, it was necessary to carefully review and prepare it to ensure compatibility with SPSS. In this study, a descriptive data analysis technique called cross-tabulation was employed to uncover, illustrate, and concisely summarize the data points in a manner that satisfies all of the data conditions. Specifically, a cross-tabulation table was utilized to describe the relationship between four dependent variables and eight independent variables. The resulting output from the SPSS analysis can be observed in Table 1, provided as an example below.

Table 1 Descriptive Cross-Tabulation Analysis of Collision Severity and Independent Variables

			Weather Conditions						
			Clear sky	High winds	Frosty	Foggy	Dusty	Rainy	Total
Collision Severity	Minor	Number	3763	2	2	9	5	123	3904
		Percent	58.4%	40%	50%	52.9%	50%	58.2%	
	Moderate	Number	2405	1	1	6	3	78	2494
		Percent	37.3%	20%	25%	35.2%	30%	36.9%	
	Severe	Number	149	0	0	0	0	4	153
		Percent	2.3%	0%	0&	0%	0%	1.9%	
	Fatal	Number	123	2	1	2	2	6	136
		Percent	2%	40%	25%	11.9%	20%	3%	
	Total		6440	5	4	17	10	211	6687

To ascertain the relevance of variables to be incorporated in the model, the Chi-square test (X^2) of independence was employed. Following this, the ordinal logistic regression model was utilized to examine the road crash factors that are closely linked with the severity level of the crash. Any variables that exhibited a statistically significant association with road crash severity level, at a significance level of 5%, were subjected to further analysis through the Ordinal Logistic Regression model.

To provide an example, let's consider the study's utilization of two nominal data variables. The first variable, 'level of crash severity,' includes four distinct categories, namely fatal ,minor injury, moderate injury, and severe injury. The second variable pertains to road surface state and is comprised of seven categories, including arid, frosty, glacier, and other. A significant application of the chi-square test is to determine if two variables are statistically independent, and this is known as the chi-square test of independence. This test analyzes the association or independence between two nominal or dichotomous variables. Before selecting the appropriate chi-square test for association, it is crucial to inspect and assess the data to be analyzed.

The findings of the chi-square test applied to the dataset are presented in Table 2. Only the variables that displayed a statistically significant association with road crash severity level, at a 5% significance level, were further scrutinized through the application of the Ordinal Logistic Regression model. The outcomes demonstrate that four variables indicate a strong correlation with road crash severity level, and their significance values were found to be less than ($p<0.05$).

Table 2 Chi-square results for the variables include in the model

Dependent Variable	Independent Variable	Value	d.f.	P-value
Level of Severity	Hour of the day	11.262	23	0.351
	Day of the week	2.183	6	0.125
	Month of the year	25.856	11	0.256
	Governorate	1.983	11	0.112
	Weather Condition	0.65	5	0.003
	Road Surface state	6.586	6	0.085
	Speed Limit	51.256	8	0.025
	Illumination Levels	2.256	5	0.002

To investigate whether the severity of collision accidents is significantly linked to eight distinct factors, the null and alternative hypotheses were established as follows:

The null hypothesis (H_0) posits that there is no significant relationship between the severity of collision accidents and the eight different factors examined in this study. On the other hand, the alternative hypothesis (H_1) states that a significant association exists between the severity of collisions and the different factors considered.

To investigate any potential links between level of accident severity and different factors, a chi-square test was performed. The study assessed eight different variables pertaining to these factors. The results indicate that out of the eight variables, four showed a significant association with level of severity as illustrated below in Table 3.

Table 3 Chi-square results for the significant variables include in the model

Dependent Variable	Independent Variable	Value	d.f.	P-value
Level of Severity	Weather Condition	0.65	5	0.003
	Road Surface state	6.586	6	0.085
	Speed Limit	51.256	8	0.025
	Illumination Levels	2.256	5	0.002

The dataset was analyzed using the Ordinal Logistic technique, and the results of the impact of associated variables on road accident severity level are presented in Table 4. Out of the eight variables examined, the study found that only four were statistically significant. The estimated β coefficients of the ordinal logistic regression analysis are reported in the results.

Table 4 Results of Ordinal Logistic Regression Analysis for Variables Impacting Collision Severity Levels

Independent Variable	Beta(β)	Std. Error	Z value	Pr(>|z|)
Hour of the day	0.06	0.03	2.03	0.041491
Day of the week	0.24	0.03	6.32	4.69E-14
Month of the year	0.52	0.03	18.25	Less than 2e-16
Governorate	-0.08	0.02	-4.05	1.92E-06
Weather Condition	-0.18	0.02	-3.65	$5.92*10^{-4}$
Road Surface state	-0.22	0.04	-4.99	2.30E-08
Speed Limit	0.00	0.00	-8.36	8.49E-15
Illumination Levels	0.06	0.03	2.56	0.040326

The results of the odd ratio and their corresponding 25% and 95% confidence intervals for each coefficient are presented in Table 5. As shown in Tables 5 and 6, the coefficient β for the weather condition was -0.18 and -0.22 for road surfce state, with odds ratios of 1.691 and 1.800, respectively. This indicates that the likelihood of a crash resulting in fatal/serious/minor injury is 1.691 times higher for weather condition and 1.800 times higher for road surfce state. Additionally, the odds of a accidents being fatal/serious/minor is highest for hour of the day, with a 1.656 times higher likelihood compared to day of the week.

Table 5 Odd ratio values and confidence interval

Independent Variable	Odds Ratio (OR)	2.5%	97.50%
Hour of the day	1.656	1.596	1.668
Day of the week	1.291	1.215	1.372
Month of the year	0.836	0.755	0.924
Governorate	0.919	.0.881	0.953
Weather Condition	1.691	0.645	0.736
Road Surface state	1.800	0.785	0.812
Speed Limit	0.997	0.997	0.998
Illumination Levels	0.999	0.856	0.965

5 Conclusion

In conclusion, this study provides valuable insights into the patterns and potential factors associated with collision accidents in Jordan. By identifying specific time periods, weather conditions, and other factors that contribute to the risk of collision accidents, the study can inform the development of targeted interventions to reduce the incidence of such accidents.

One of the key contributions of this work is its emphasis on the need for a multifaceted approach to addressing collision accidents in Jordan. Rather than focusing solely on one factor, such as speed limits or road infrastructure, the study highlights the importance of considering a range of factors, including traffic volume and weather conditions. This approach can help to ensure that interventions are effective in addressing the specific causes of collision accidents in Jordan.

Another important contribution of this work is its recommendations for further research. The study identifies areas where additional research is needed, particularly in the case of collisions that involve multiple factors. This information can guide future research efforts and help to build a more comprehensive understanding of the causes and consequences of collision accidents in Jordan.

Overall, the study provides a valuable contribution to the field of road safety in Jordan, and its findings can inform the development of policies and interventions aimed at reducing the incidence of collision accidents. However, there is always room for improvement, and future studies could build on this work by incorporating additional data sources, such as accident reports or driver behavior surveys, to further explore the factors contributing to collision accidents in Jordan.

6 Recommendations

Further research could investigate the relationships and interactions between the various factors that contribute to traffic collision accidents in Jordan, such as traffic volume, road surface conditions, weather conditions, and driver behavior, to inform the development of more effective government programs and policies aimed at reducing their incidence. Additionally, future research could explore the potential for using predictive modeling techniques based on historical data to forecast the likelihood and severity of traffic collision accidents in high-risk areas, which could help government agencies to implement proactive measures to reduce their risk. By improving our understanding of the complex factors that contribute to traffic accidents and using predictive modeling, future research could help reduce the incidence and severity of traffic collision accidents in Jordan.

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Design of logistic criteria to establish healthcare facilities in vulnerable regions in Mexico
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Design of logistic criteria to establish healthcare facilities in vulnerable regions in Mexico

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Keywords: vulnerable communities, medical supply, distribution networks, facility planning.
Abstract: According to the World Health Organization (WHO), health inequities refer to those dimensional, measurable, and avoidable differences between socially, economically, demographically, or geographically defined population groups. In Mexico, despite several advances in health services and infrastructure, there are health inequities in rural communities, particularly those with indigenous population. These communities have limited or non-existent healthcare facilities, medical equipment, transport infrastructure, medicines, and human resources such as doctors and nurses. In this work, a conceptual design of a healthcare network is proposed to serve a region with several rural communities with limited healthcare resources. The designed network allocates rural communities to the most appropriate facilities based on (a) a vulnerability community index, and (b) a facility service index. The application of the conceptual network led to a hierarchical referral scheme between communities and different types of healthcare facilities to improve medical services and infrastructure planning. These results can support the decisions aimed to expand already existent facilities, replace multiple basic facilities with an appropriate number of larger and more advanced facilities, and determine the transportation infrastructure required to reach these facilities.

1 Introduction

According to the World Health Organization (WHO), health is the result of a complete state of well-being which is achieved by a reduction in disease occurrence and improvement in medical care, ensuring that people can live each stage of their lives with dignity and quality of life. Thus, health is a fundamental human right and all people must have fair access to healthcare services [1]. However, within the sociocultural context of rural and indigenous communities, there are health inequalities which affect the fair access to healthcare services [2]. Health inequalities are defined as "systematic, avoidable and unfair differences in health outcomes that can be observed between populations, between social groups within the same population or as a gradient across a population ranked by social position" [3].

In Mexico, the increase in life expectancy indicates the positive effect of improvements in social conditions and health policies. However, this is not correlated with the life expectancy of the population in rural and indigenous communities which account for 20% of the country´s population. In fact, there is a significant gap in socio-economic and developmental indicators between indigenous and non-indigenous populations [4]. As an example of the health implications of this gap, monitoring, diagnosis and treatment of cancer have led to improved survival in people living in developed cities than in rural and indigenous communities [5]. This is associated with access to high-quality healthcare services which is dependent of economic, geographic and social factors. This has contributed to health disparities across the country where there is limited coordination between public health and healthcare system initiatives [6].

This limited coordination has been a factor for inefficient planning of services and infrastructure which includes facility location, allocation of communities, medical referrals, and land transportation. Not having appropriate infrastructure negatively impacts the eligibility of communities for the establishment (or allocation) of resources and assistive governmental programs [4].

In this context, the logistic field can contribute with a structured approach to improve the coordination between healthcare facilities. It also can contribute to determine the types of required facilities (i.e, health homes, clinics and hospitals) considering the communities' characteristics of population density, geographical location, and infrastructure.

Hence, the present work addresses this problem from a logistic approach, proposing the conceptual design of a healthcare network to serve a region with several vulnerable communities with limited healthcare facilities. The designed network allocates rural communities to the most appropriate facilities based on the following innovations: (a) a vulnerability community index, and (b) a facility service index. The application on the case study, which consisted of indigenous and rural communities within the municipality of Zacapoaxtla in the Mexican state of Puebla, led to a hierarchical referral scheme between communities and different types of healthcare facilities to improve medical services and infrastructure planning. These results can support the decisions aimed to expand already existent facilities, replace multiple basic facilities with an appropriate number of larger and more advanced facilities, and determine the transportation infrastructure required to reach these facilities. Hence, it is expected that the proposed network design can reduce inequality in healthcare services for the inhabitants of indigenous and rural communities in developing economies.

The advances of the present work are described in the following sections: in Section 2 a review of the healthcare services in Mexico and the municipality of Zacapoaxtla is presented; then, the methodological steps to design the network are presented in Section 3; the results of the application on the case study are analysed and discussed in Section 4; finally in Section 5 the conclusions and future work are presented.

2 Healthcare conditions in rural communities

Due to a predominant sedentary lifestyle in Mexico, the occurrence of chronic degenerative diseases have overcome the incidence of infectious diseases. In general, the Mexican population has a high prevalence of chronic diseases and obesity: 18.4% of adults are currently diagnosed with hypertension and 10.3% diabetes. With respect to risk factors, 36.1% of the adult population is obese while 11.4% smokes [7].

Regarding the health system in Mexico, it is difficult and complex, not only in terms of the citizen's perception, but also for managers, health employees, doctors, nurses, specialists, and health workers [8]. Some regions are characterized by precarious medical service delivery, poor health infrastructure, and difficult access to healthcare [9,10]. Particularly, southern regions are characterized by a high prevalence of indigenous populations living in conditions of high marginality and economic inequality [10]. In such cases, networks are the main resource to deal with health-related issues, food, medicine, and out-of-the-pocket medical expenses [11,12].

In rural indigenous communities, health services are provided through a basic structure of "health homes" which are managed by a member of the community who has been trained (a general practicioner or doctor) to care patients with mild illnesses such as the common cold, follow-up of pregnancies, non-severe respiratory and diarrheal infections. In more severe cases, patients are referred to the nearest (or geographically reachable) public clinic or hospital. The service hours in the health homes are 4-hours a day, adapted to the needs of the communities and support in case of emergencies. The Ministry of Health provides these facilities with healing material, office and medication codes. The information of the activities carried out in these facilities is recorded and reported to the state authorities.

In emergency situations, the volunteering general doctors (who oversee the health homes) have the responsibility of referring patients to intensive care units located in these communities (i.e., clinics or hospitals). It is important to mention that not all rural and indigenous communities have healthcare units and there is an absence of mobile phone or internet signal. This leads to inefficient communication between doctors in the different healthcare facilities to make a proper referral of the patients.

Regarding clinics, these facilities have a basic infrastructure of furniture, equipment, instruments, medicines and biological products. This affects the diagnosis of the doctors, as sometimes they must perform assessments of patients with chronic complications with basic instruments such as sphygmomanometers and stethoscope. The operative team frequently consists of a general practitioner, an intern, a director, and two nursing assistants. The services which are provided are outpatient general medicine, preventive medicine, and emergency care. Also, they promote the following programs: vaccination, care of chronic degenerative diseases, epidemiological surveillance, child malnutrition, prenatal control and sexual education. General medical consultation is provided from Monday to Friday within the schedule of 8 a.m. to 4 p.m. However, emergencies can be referred 24-hours a day.

Because health service demand is large, sometimes it cannot be covered by the personnel of the clinic. Thus, there are patients who must travel from their communities to other municipalities to receive the required medical attention. In example:

- patients living in the Tacuapan community must be referred to the Ixtepec hospital, which is located two hours away from the nearest Santiago Yancuitlalpan municipality.
- the municipality of Cuetzalan in Puebla has 18 medical units (1.5% of the total number of medical units in the state), 50 doctors (0.6% of the total number of doctors in the state) and the ratio of physicians per medical unit is 2.8, compared to the ratio of 7.5 in the state. This represents a low concentration of health professionals available for the attention of the population [13].

Mortality of patients who have been urgently transferred to these units has been associated with ineffective processes to contact ambulances and doctors, difficulties to reach the communities due to poor or null

road infrastructure, absence of ambulances, and long distances between the clinics / hospitals and the communities. Within the aspect of transportation, most clinics have no ambulances, so patients must arrange private transportation. The mortality risks are more significant in communities without basic services (drinking water, electricity) or roads.

Hence, it is necessary to generate the necessary structure in the organization of the services at the following levels: general medicine consultations (first level, I); healthcare and disease prevention, nursing, and vaccinations (second level, II); and highly complex medical procedures such as surgeries which require advanced technology and specialized equipment (third level, III). Here it is important to mention that patients referred from levels I and II frequently present pathologies that require attention of high diagnostic and treatment complexity, however, these have minimum coverage.

3 Design methodology

The present research work analysed and evaluated the healthcare units that provide coverage to 501 rural and indigenous communities in the municipality of Zacapoaxtla in the Mexican state of Puebla. As presented in Figure 1, this municipality is located within the northern region of Puebla, with parallel geographical coordinates between 19°44'18" and 19°59'18" north latitude, and meridians between 97°31'42" and 97°37'54" west longitude [14,15]. Figure 2 presents an overview of the methodological stages considered to design the healthcare network.

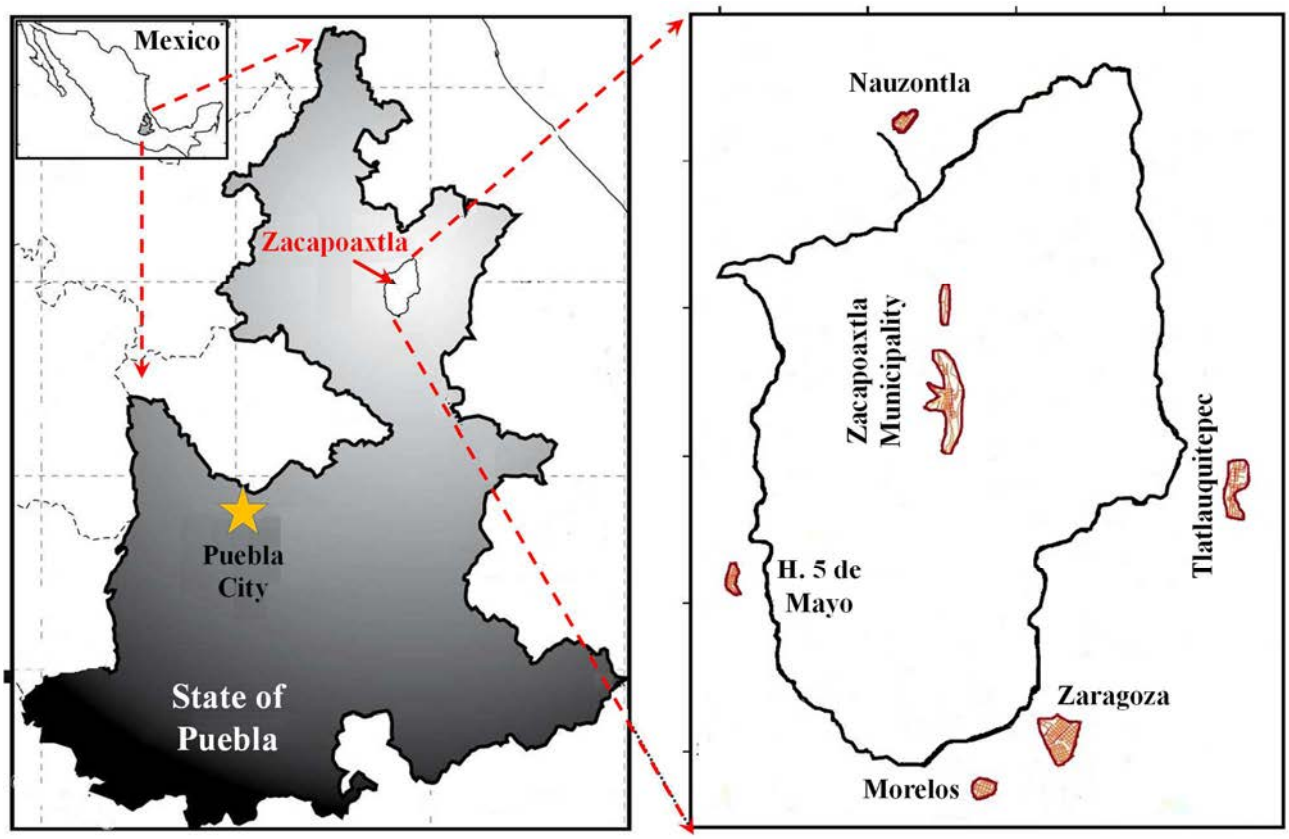


Figure 1 Geographical location of the Municipality of Zacapoaxtla (adapted from [15])

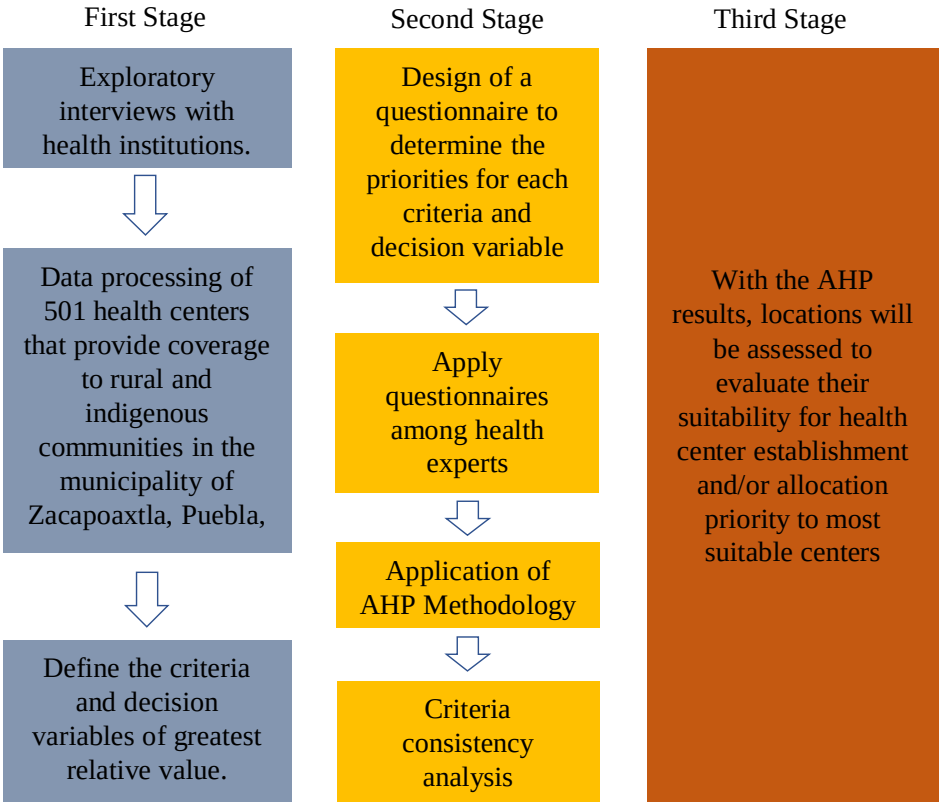


Figure 2 General structure of the methodology for design the health service network for rural communities in Zacapoaxtla

3.1 First stage: criteria for community eligibility and facility infrastructure

In this stage, exploratory interviews were performed with directors and doctors who work in health institutions that provide services in some indigenous and rural communities. The interviews were designed to determine the most important criteria to evaluate the eligibility of each location for the establishment of a new healthcare facility, or improving an already existing facility. These criteria were the following:

- Number of inhabitants: communities with low population density had limited or non-existent basic healthcare services.
- Geographic accessibility: the geographic locations of the communities represent physical barriers for patient mobility and access to appropriate healthcare facilities.
- Available Infrastructure: the existing healthcare facilities are a major factor in healthcare service quality. It is also important for elimination and upgrading plans. In this context, the following facilities were identified:
  - Health Homes: these are small spaces or rooms which are frequently loaned by families within their home premises to provide intermittent basic care (i.e., general consultation, application of seasonal vaccines, general monitoring of glucose / blood pressure, informative health recommendations, etc.). One doctor and one nurse are the main health personnel at these premises.
  - Regional Clinic: these are medium-sized premises with limited beds and rooms. These are managed by the Ministry of Health and are frequently located near the local government house. These clinics are mainly used for stabilization care, and they are assisted by three-to-six doctors and nurses.
  - Hospitals: these are medium and large-sized facilities where complex procedures such as surgeries can be performed. There are doctors with different specializations and equipment. These facilities are assisted by 10 to 15 doctors and nurses.

3.2 Second stage: assessment of community eligibility

In this stage, the Analytic Hierarchy Process (AHP) decision-making model was applied to assess the location of each community to determine its suitability to establish a healthcare facility. For this purpose, the criteria defined in the previous section were considered.

AHP is an analytical method where quantifiable and non-quantifiable data can be analysed to support decision making [16]. This is important because experience and knowledge mixed with data are the basis to make appropriate decisions [17]. This tool was developed by Thomas Saaty and it is performed in two steps [16]:

- A hierarchical structure is designed to associate criteria with alternatives.
- The assessment of each identified criterion with each alternative is computed as a comprehensive metric. This is performed through comparison of pairs (criterion vs. criterion, alternative vs. alternative for each criterion). In this regard, the Saaty scale (see Table 1) provides a metric (score) to prioritize and weight the importance or contribution of one element over another.

Table 1 9-point Saaty scale for paired comparisons

Numerical Scale	Verbal Scale	Explanation
1	Equal importance	Both elements contribute equally to the property or criterion
3	Moderately more important one element than the other	Judgment and previous experience favor one element over the other.
5	Strongly more important one element than the other	Judgment and prior experience strongly favor one element over the other.
7	The importance of one element is much stronger than the other	One element dominates strongly. Its dominance is proven in practice.
9	Extreme importance of one element over the other	One element dominates the other with the largest possible order of magnitude.
2,4,6,8	Intermediate decision values	They are intermediate decision values

The importance of the AHP methodology is in the determination of relative weights to qualify the alternatives. If there are n criteria in some specific hierarchy, the AHP establishes a $n \times n$ pairwise comparison matrix A, which measures the decision maker's judgment of importance concerning each criterion. The pairwise comparison is performed such that the criterion in row i ($i = 1, 2, 3, \ldots, n$) is scored against each alternate criterion. If $a_{ij} = 1$ it represents that i and j have equal importance for the expert. Then $a_{ij} = 9$ indicates that i is extremely more important than j (in contrast, $a_{ji} = 1/9$). Note that the matrices have to fulfill a series of features:

- Reciprocity: if $a_{ij} = x$, then $a_{ji} = 1/x$, with $1/9 \leq x \leq 9$.
- Homogeneity: if the elements i and j are considered equally important, then $a_{ij} = a_{ji} = 1$.
- Consistency: it is satisfied that $a_{ik} + a_{kj} = a_{ij}$ for all $1 \leq i, j, k \leq q$.

Figure 3 presents the AHP structure considered for this work. Note that the 501 locations represent the alternatives to be assessed based on the following criteria: number of inhabitants, geographic accessibility, and infrastructure for healthcare facilities. Then, Table 2 presents the type of questions established when assigning the Saaty weights for the comparison of importance between all criteria. In other words, this instrument seeks to prioritize the factors that influence healthcare services and determine the relative weight between them, for each of the different alternatives.

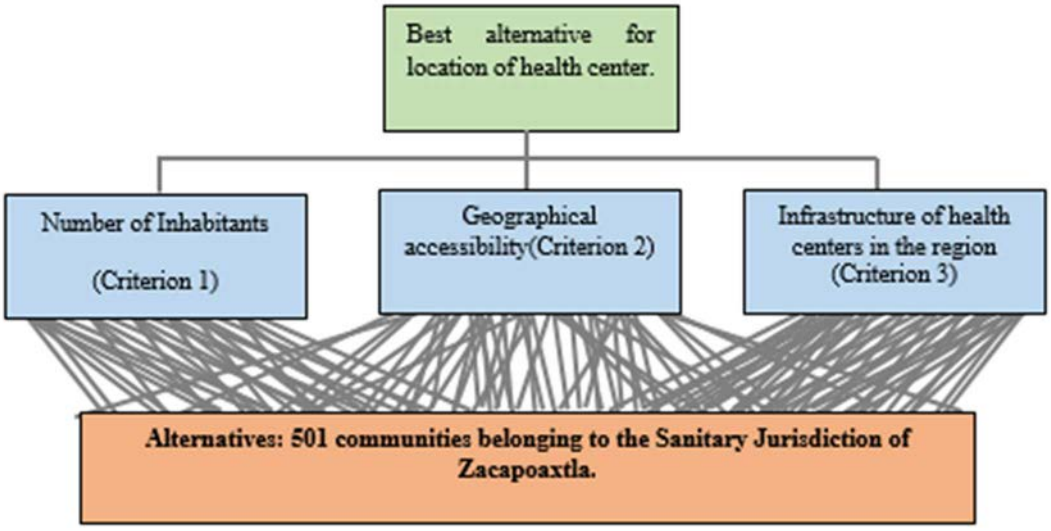


Figure 3 AHP hierarchical structure

It is important to mention that validation of the Saaty weights was performed with 15 experts (directors and doctors who have worked in healthcare institutions in rural communities). Each expert was asked individually to make an estimate of the Saaty score for each question. A group meeting was not required to avoid biases caused by group interaction.

Table 2 Questions to weight importance scores between criteria

Questions	Moderately important	Strongly more important	Much stronger the importance	Extreme importance
For the location of a health center in a rural community, how important is the total number of inhabitants with respect to geographic accessibility?	3	5	7	9
For the location of a health center in a rural community, how important is the total number of inhabitants with respect to the healthcare infrastructure?	3	5	7	9
For the location of a health center in a rural community, how important is geographic accessibility with respect to healthcare infrastructure?	3	5	7	9

Table 3 presents the comparison matrix for all criteria and the final composite score. As shown, the number of inhabitants in the community is the most important criterion to establish a healthcare facility.

Table 3 Weighted scores for each criterion

	# Inhabitants	*Geo Accesibility*	*Infrastructure*	*Score*
# Inhabitants	1	9	3	**0.66394895**
Geo Accesibility	1/9	1	3	**0.20075623**
Infrastructure	1/3	1/3	1	**0.13529481**

Then, as presented in Figure 3, for each criterion all alternatives (communities) were compared with each other. By integrating these comparisons with the criterion score, a final *AHP Score* was computed for each community. Note that this metric represents how a community complies with the eligibility criteria for the establishment of a healthcare facility. Hence, large values involve better infrastructure and geographic accessibility. In contrast, small values involve poor or null infrastructure and difficult geographic accessibility.

The *AHP Score* is proposed as a *vulnerability index* to support the decision regarding the type of facility to be established in the community. Here, communities which small values have higher vulnerability for the establishment of a facility. Although this would represent a barrier for the establishment of large facilities such as a clinic or hospital, it provides the analysis to support the need for improved road infrastructure.

3.3 Third stage: eligible communities for each facility type

From the *AHP Scores* estimated for all locations, the average (μ) and standard deviation (σ) values were computed. As presented in Figure 4, if considering μ as the cut-off point to establish a healthcare facility, approximately 50% were suitable locations.

Then, μ and σ were used as metrics to define statistical intervals to establish the most appropriate location for each type of facility. These intervals were considered as *facility service indexes* which, as presented in Figure 4, were set at $[\mu \rightarrow \mu + \sigma]$, $[\mu + \sigma \rightarrow \mu + 2\sigma]$ and $[\mu + 2\sigma \rightarrow \mu + 3\sigma]$ for Health Homes, Clinics, and Hospitals respectively.

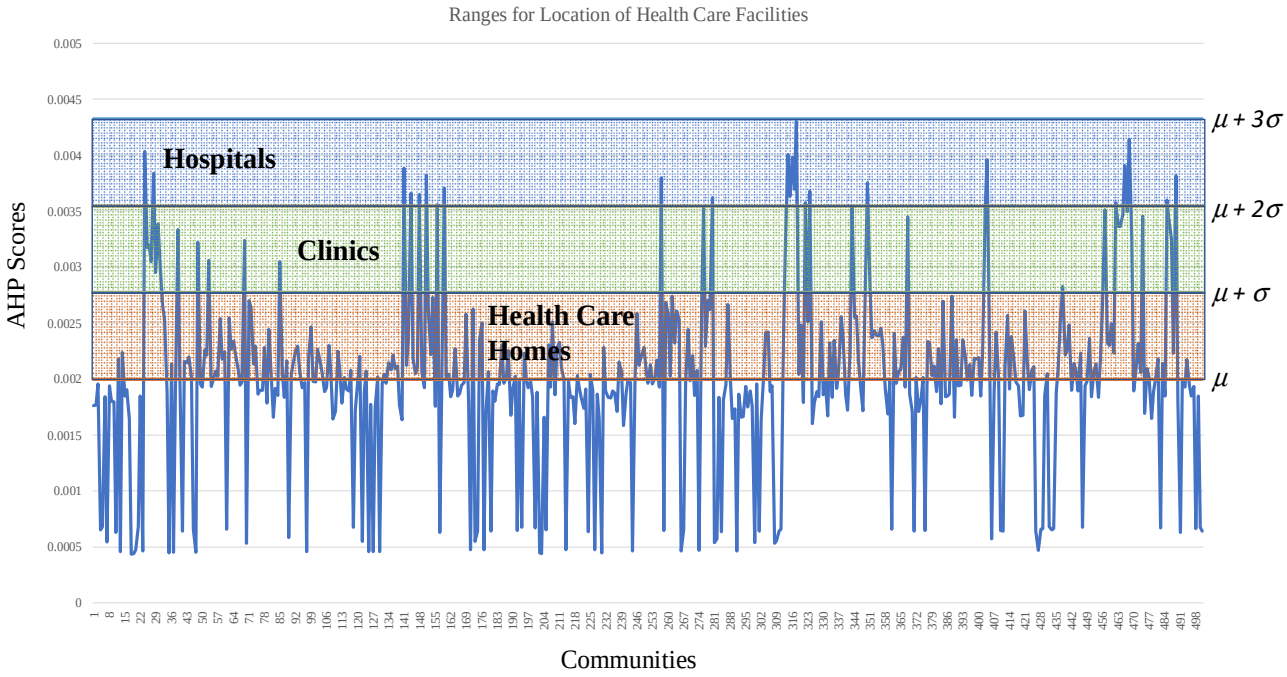


Figure 4 AHP scores and intervals to define eligible locations for each type of healthcare facility

4 Analysis of results

Table 4, Table 5, and Table 6 present the details of the communities eligible for health homes, clinics and hospitals within the region of Zacapoaxtla. There are 165,728 inhabitants through all communities, and according to Table 4, there are 77,459 inhabitants (46%) in the 198 communities which are eligible for equipped health homes. Then, according to Table 5, there are 22,575 inhabitants (14%) in the 28 communities which are eligible for equipped clinics. Finally, according to Table 6, there are 33,491 inhabitants (20%) in the 24 communities which are eligible for hospitals. The remaining inhabitants (20% within the communities with scores lower than μ) must be served by the closest health homes, clinics or hospitals which are located in the eligible communities.

Figure 5 presents all communities, marking those eligible for each type of healthcare facility. Note that there are three communities which are located far away from the cluster of communities. According to the AHP analysis, these were scored within the first interval, thus, they are candidates for the establishment of health homes which can transfer patients to the communities with clinics or hospitals.

In contrast, there are two locations which are not suitable for the establishment of any healthcare facility. However, these are located closer to the cluster of communities, and thus, to healthcare facilities. Within the main cluster of communities and municipalities, a homogeneous distribution of non-eligible locations with candidate locations for healthcare facilities is observed. Thus, a suitable allocation between all communities and healthcare facilities can be performed.

Table 4 Communities suitable for allocation or improvement of health homes

#	Community	Population	#	Community	Population	#	Community	Population
1	TIERRA NUEVA	321	67	BARRIO ALTO	394	133	TAMALAYO	499
2	EJIDO PALO GACHO	360	68	AMATETEL	617	134	TANHUISCO DEL C.	475
3	EL CARMEN	271	69	ATEHUETZIN	647	135	TEHUAGCO	473
4	ANIMAZCO	185	70	COL. MORELOS	435	136	TEPANZOL	522
5	CUAUHTEMOC	296	71	CONTA	562	137	TEPEHICAN	420
6	URUAPAN	210	72	CUAXOCOTA	250	138	ATALPA	485
7	LA LAGUNILLA	310	73	LIMONTITAN CHICO	417	139	IXMATLACO	396
8	SAN FCO. ATECACALAX	304	74	LOMAS DE ARENA	289	140	TEZIUTANAPA	266
9	COPALES	334	75	LLAGOSTERA	380	141	ACOCOGTA	462
10	LA UNION	219	76	MECATEPETL	224	142	S.A CHAGCHALTZIN	354
11	ACAXILOCO	382	77	EJIDO HUEYTAMALCO	430	143	TUNEL II	217
12	ALAHUACAPAN YANCTL.	350	78	PALMAGTITAN	214	144	XALTENANGO	429
13	EQUIMITA XOCOYOLO	255	79	TACOTALPA	415	145	BUENA VISTA	427
14	LA GALERA XOCOYOLO	224	80	TEPACTIPAN	571	146	CANAL	228
15	IXTAHUATA CUETZ.	594	81	TETEYAHUALCO	395	147	XALTETA	288
16	LIMONCO	319	82	TILAPA	427	148	PABLOGCO	392
17	PAHPATAPAN	362	83	TLACUILOLAPAN	349	149	ATIOYAN	729
18	TACUAPAN YANCTL.	597	84	SOLORZANO	230	150	TOZANCO	770
19	TAXIPEHUAL CUETZ.	390	85	COLONIA LA VIRGEN	302	151	HUITZILTEPEC	438
20	TENEXTEPEC+ MONTE ALTO	432	86	PAPALOAPAN (HUEYTAMALCO)	399	152	REYES DE VALLARTA	522
21	TEPANGO ZACAT.	351	87	EL CRUCERO	305	153	RICARDO FLORES MAGON	331
22	TEPETITAN ZACAT.	271	88	LA CRUZ DE CHACA	249	154	EL TUTI	295
23	XALPANZINGO TZICUIL.	732	89	LA TRANCA + CATINIX	209	155	ALTO LUCERO	405
24	XALTIPAN TZINACAPAN	673	90	CHAGCHALOYAN DE Z.	282	156	CHAPAS	319
25	XOCOYOLO	296	91	S.A. TLALZINTAN	623	157	BARRIO CHIQUITO	327
26	ZOQUITA TZICUIL.	409	92	SAN MIGUEL ACATENO	292	158	S.A. COYOTITLAN	365
27	TENANGO TZICUIL.	397	93	XINACHAPA DE A.	421	159	AGUAJE ATOLUCA	351
28	XOCHICAL	501	94	SAN JOSE ACOTZOTA	473	160	LA PALMA (XIUTETELCO)	493
29	CAXALTEPEC	245	95	PARAISO	278	161	LA REFORMA (XIUTETELCO)	287
30	PESMAPAN ZACATIPAN	313	96	CHAGCHALOYAN DE I.B.	295	162	VISTA HERMOSA	280
31	QUEZAPAN ZACATIPAN	240	97	COSOLTEPEC	215	163	ZAPOTE	611
32	CHICUEYACO TZINACAPAN	368	98	PEZMATA + PAPALOCONTITAN	316	164	LA CANTERA	470
33	TUZAMAPAN XILOXOCH.	450	99	SAN MARTIN	728	165	LA POSTA	313
34	XIUTECUAPAN XILOXOCH.	407	100	ESCATACHUCHUT	616	166	CRUZ VERDE	635
35	CACATECUHUTA XILOX.	258	101	CAXTAMUSIN	221	167	ATZALAN	292
36	COSAMALOMILA	327	102	PATY	879	168	LA MANZANILLA	262
37	TECOLTEPEC TZINAC.	534	103	TAKALZAPS	498	169	YAUTETELCO	284
38	SANTIOPAN YOHUALICH	391	104	ECATLAN	738	170	CUAUTAMANIS	242
39	CAPOLA YANCTL.	312	105	TECPANZINGO	583	171	AMATITAN	279
40	TATAHUITALTIPAN	245	106	SAN RAFAEL AXOLOTLA	503	172	HUAPALEGCAN	628
41	REYES HOGPAN DE HGO.	482	107	TEPANYEHUAL	345	173	OCOTEPEC DE C.	351
42	CUAMONO CUETZ.	221	108	LA UNION ATIOYAN	257	174	TZONTECOMATA	386
43	LIMONTITA ZACATIPAN	370	109	BIBIANO HERNANDEZ	672	175	XALTIPAC	551
44	TECUAHUTA ZACATIP.	243	110	IGNACIO ZARAGOZA	407	176	CHICUACENCUAUTLA	300
45	LAS HAMACAS ZACATIPAN	217	111	KUYUMCHUCHUT	733	177	XOCOYOLAPAN	250
46	CUAUTAMANCA	258	112	SANTA CATARINA	641	178	AHUATA	358
47	CAHUAYOLCO TZICUILAN	338	113	LA LIMA	704	179	TATEMPAN	453
48	ATEMOLOJ CUETZ.	253	114	JUNTA ARROYO ZARCO	302	180	ATEMEYA	258
49	TIXAPANTENO	218	115	COACALCO	490	181	TEPANTILOYAN	297
50	TALCUILOL CUETZ.	236	116	TEXCALACO	491	182	CALCAHUALCO	317
51	ZOQUIACO	304	117	COYOPOL	481	183	CUACUILCO PB	639
52	TENANIKAN	269	118	LOMA BONITA	238	184	GONZALO BAUTISTA	424
53	XILCUAUTA	351	119	SAN M. CAPULINES	546	185	IXTACAPAN	413
54	CUATRO CAMINOS	275	120	MAXTACO	573	186	JILOTEPEC (ZACAPOAXTLA)	555
55	ZILTEPEC	288	121	EL FRESNILLO	573	187	NEXPANATENO	357
56	LA AGUARDIENTERA	292	122	ACAMALOTA	211	188	COL. INDEPENDENCIA	240
57	LOS PARAJES	445	123	AJOCOTZINGO	495	189	COHUATZALPAN	423
58	ASERRADEROS	324	124	CALATEPEC	437	190	COL. INSURGENTES	248
59	COATZALAN + TLATZINTAN	307	125	CUACUALAXTLA	252	191	SAN CARLOS	276
60	TENEXTEPEC	278	126	CUAUTLAMINGO	603	192	MORAGCO	217
61	CUAPALTEPEC	313	127	CHICUACO	461	193	OCTIMAXAL 1º SECCION	235
62	PUTAXCAT	767	128	ELOXOCHITAN	374	194	NEXPAN (ZACAPOAXTLA)	321
63	CHILOCOYO GPE.	426	129	HUAXTLA	602	195	XICOTENCATL 4A. SECCIÓN	298
64	KUWIC-CHUCHUT(S.F.I.M.)	767	130	EL CARMEN ILITA	608	196	SN. JOSE BUENA VISTA	358
65	TETELILLA COPLADE	290	131	JILIAPAN	313	197	XALEHUALA	211
66	PASO REAL	237	132	EL PROGRESO	461	198	AMATLAN	317

Table 5 Communities suitable for allocation or improvement of clinics

#	Community	Population
1	SAN AMBROSIO = LAS CANOAS	631
2	SAN NICOLAS	751
3	TEZOMPAN	544
4	EL CUATRO	468
5	LAS DELICIAS	855
6	HUEXOTENO	520
7	GACHUPINATE (RANCHO N.)	798
8	RANCHO NUEVO	679
9	CUAHUTAPANALOYAN	551
10	XALCUAUATLA REYES H.	703
11	XALTZINTA ZACATIPAN	543
12	CHIPAHUATLAN	996
13	HUEHUEYMICO	891
14	GOMEZ ORIENTE	1008
15	OCOTA	921
16	PLAN DE GUADALUPE	875
17	ILITA	916
18	SAN ISIDRO	1181
19	PAHUATA	871
20	FCO. I. MADERO	971
21	PROGRESO	839
22	TALZECUALA	839
23	TEZOCOYOHUAC	921
24	XALTIPAC	948
25	H. 5 DE MAYO	719
26	XILITA	918
27	ACUACO	887
28	LAS TRANCAS E.E.C	831
		22575

Table 6 Communities suitable for allocation or improvement of hospitals

#	Community	Population
1	CALA NORTE	1677
2	TANHUISCO	1367
3	YOPI	1478
4	ANALCO	1137
5	TEPEPAN	1131
6	LIPUNTAHUACA	1515
7	AHUATEPEC (HUEYAPAN)	1037
8	NEXPAN	1164
9	IGNACIO ALLENDE	1324
10	PUMACACHOCOCHUCHUT	1114
11	IXTICPAN	1647
12	IXTLAHUACAN	1117
13	SAN DIEGO	1629
14	SAN JUAN TEZONGO	1151
15	XOLOATENO	2899
16	CUAXOSPAN	1066
17	SECCION 23	1147
18	PEZMATLAN	1221
19	SANTIAGO	1617
20	NEXTICAPAN	1066
21	XALTETELA	1514
22	SAN FRANCISCO ZACAPEXPAN	2044
23	NANACATLAN	1072
24	MORELOS (ZARAGOZA)	1357
		33491

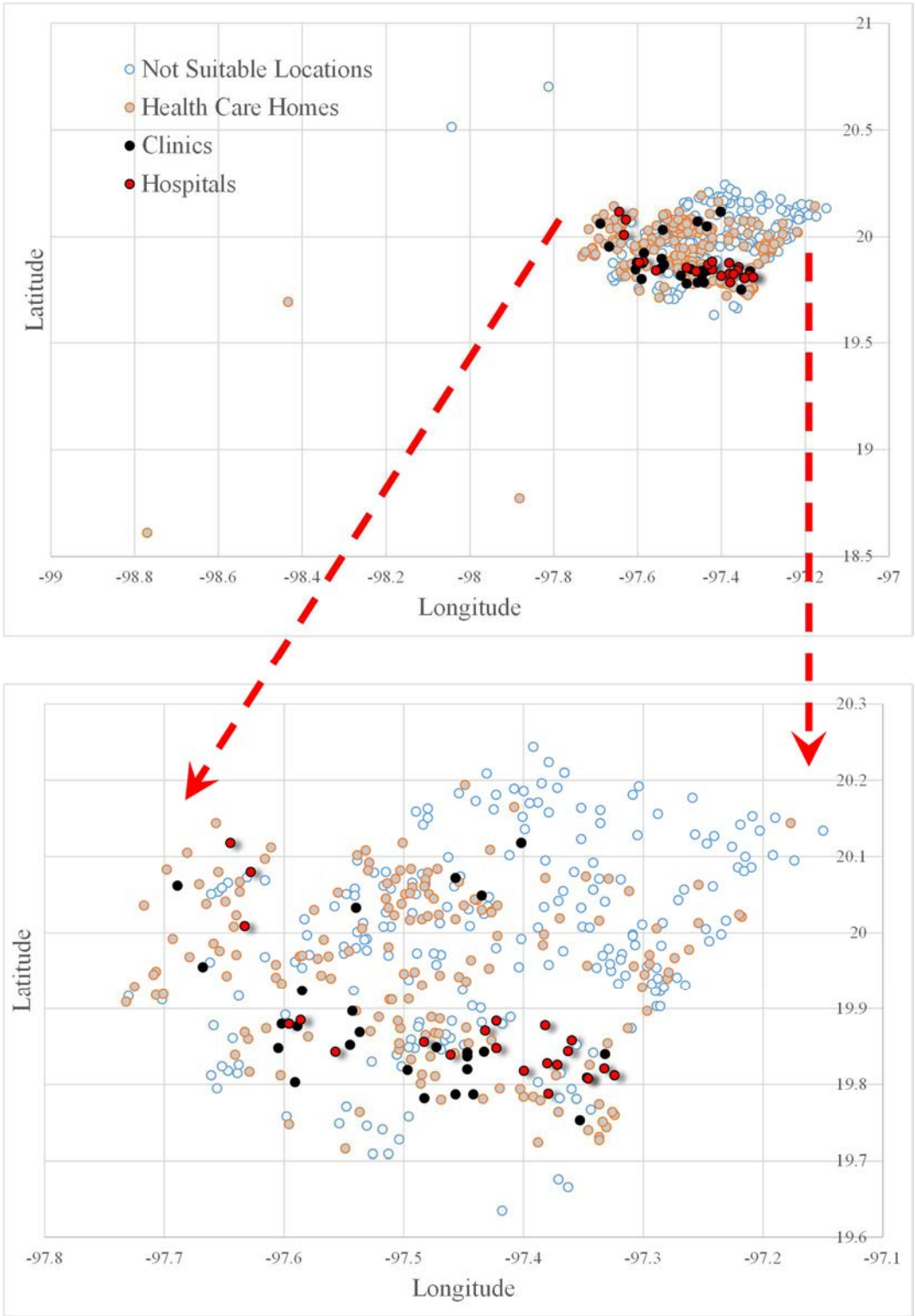


Figure 5 Geographical visualization of non-eligible locations, and locations suitable for improvement or establishment of health homes, clinics, and hospitals

Design of logistic criteria to establish healthcare facilities in vulnerable regions in Mexico
Irene-Crisely Perez-Balboa, Santiago-Omar Caballero-Morales, Diana Sanchez-Partida, Patricia Cano-Olivos

Once the locations were identified, a suitable allocation of communities to healthcare facilities must be performed to make appropriate medical referrals. For this, it is expected that policies regarding optimal criteria to establish the medical needs are developed by the Ministry of Health. Figure 6 presents the hierarchical referral scheme between all communities and healthcare facilities. Note that, as equality is sought with this scheme, communities in non-eligible locations can be referred directly to health homes (NSL-HCH), clinics (NSL-C) and hospitals (NSL-H). Then, patients in communities with health homes can be referred directly to locations with clinics (HCH-C) and hospitals (HCH-H). Finally, patients in communities with clinics can be referred directly to hospitals (C-H).

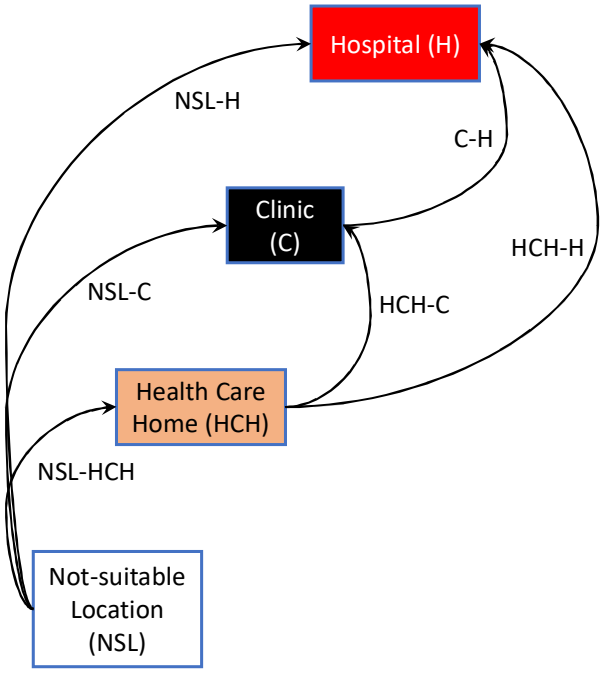


Figure 6 Hierarchical referral decision model for the health service network

Figure 7 presents the allocations of patients in non-eligible locations to facilities in locations with (a) health homes, (b) clinics, and (c) hospitals. This allocation was performed considering the minimum geographical distance metric [18]:

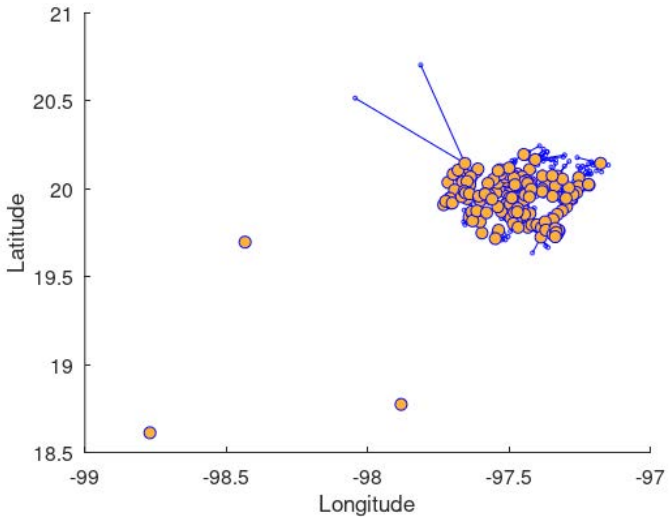
$$d_{AB} = R \times Arcos(sin\varphi_A sin\varphi_B + cos\varphi_A cos\varphi_B \cos(\lambda_A - \lambda_B)). \quad (1)$$

In (1), the distance (arc length) between two locations (A and B) is computed from their latitude coordinates (φ_A and φ_B) and longitude coordinates (λ_A and λ_B). R is the Earths radius which is approximately equal to 6371 km.

Figure 8 presents the allocations of patients in locations with health homes to facilities in locations with (a) clinics, and (b) hospitals. Then, Figure 9 presents the allocations of patients in locations with clinics to facilities in locations with hospitals. These results are important because they contribute to determine an optimal number of required facilities. In example, if considering the minimum distance criterion, there are 10 locations for hospitals which would serve only its community. In such case, resources can be optimized to increase the infrastructure of other hospitals in the network and reduce the number of facilities.

Specifically, cluster W involves three locations for hospitals which would serve five locations with clinics. Due to economical restrictions, and geographic proximity, a single hospital could be established to serve all allocated clinics. The same can be performed for cluster X which involves two locations for hospitals (which are very close) and five clinics. Note that due to geographic proximity, and optimization of resources, all these facilities could be replaced by a single clinic or hospital. This reasoning can be applied to clusters Y and Z. Specifically for cluster Z, there are more candidate locations for hospitals than for clinics (10 vs. 2 respectively). If considering its proximity to cluster Y, cluster Z could be eliminated from the selection process and allocate all communities within it to the health facilities in cluster Y. These are the kind of decisions which can be performed with the results of the present work.

(a)



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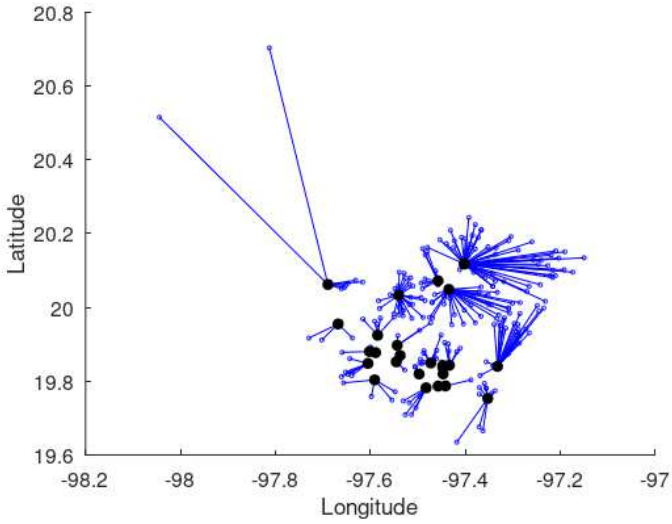

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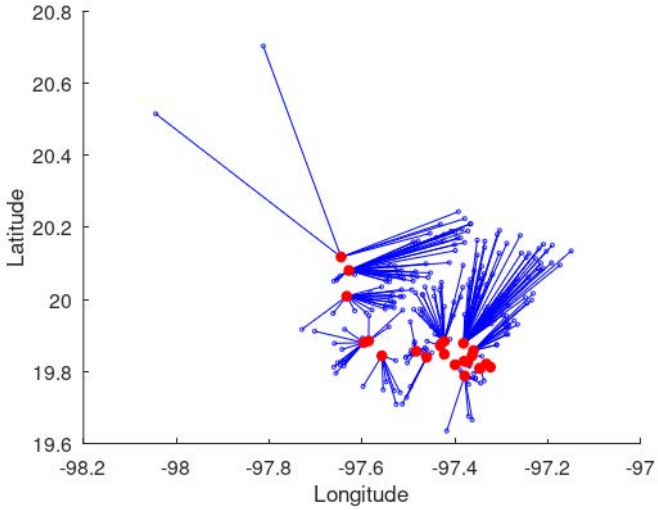
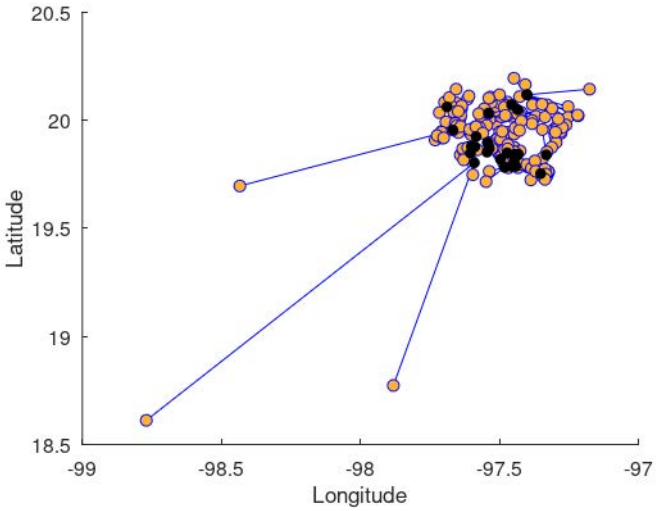


Figure 7 Allocations between (a) NSL-HCH, (b) NSL-C and (c) NSL-H

(a)



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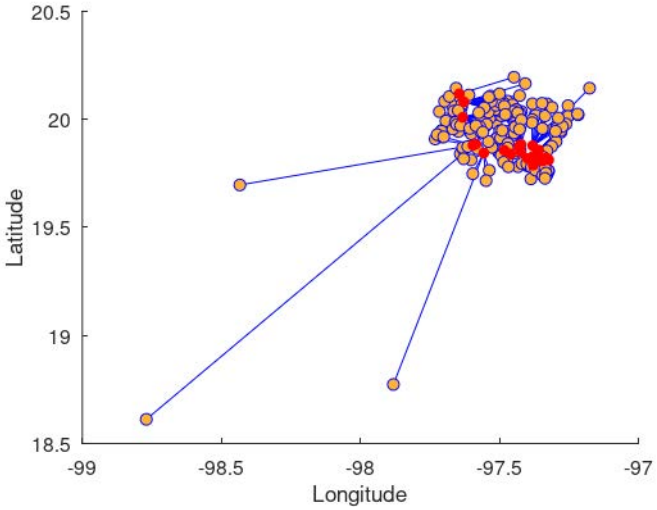

Figure 8 Allocations between (a) HCH-C, and (b) HCH-H

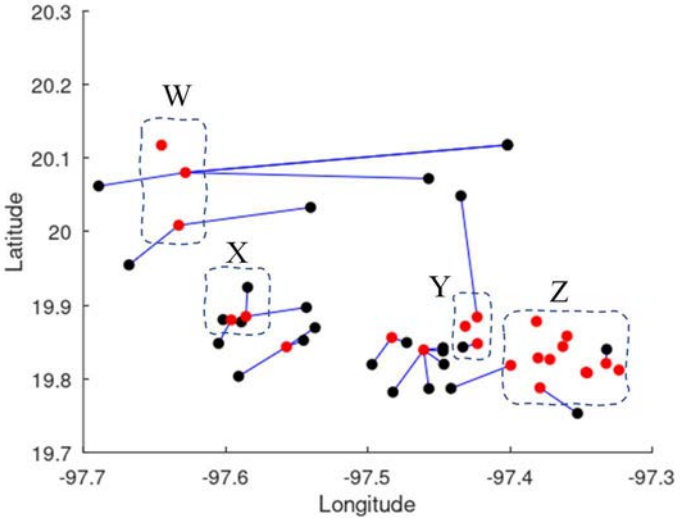

Figure 9 Allocations between clinics and hospitals (C-H)

5 Conclusions and future work

It is important that the design of the health service network considers governmental policy development. As analysed in [19] policies are important to regulate informal community participation (interactions between health program supervisors and local authorities, and interactions between clinic doctors and villagers) as this has an impact on local health program implementation.

Although governmental economic resources for investment in infrastructure is limited, the present work provides a benchmark regarding the potential number of locations to improve or establish three types of healthcare facilities: healthcare homes, clinics, and hospitals. As presented in Figure 6 a hierarchical decision model, supported by appropriate referral policies and criteria, can be used to optimize the transport of patients throughout the network.

As presented in Figure 9, some locations for hospitals are geographically very close and would only serve its community. As economic resources are deemed crucial for governmental decisions, the present work contributes with the data to support specific decisions regarding the number of facilities of each type to be established within a certain region. This would also include other decisions involving capacities (number of beds, waiting rooms, surgery equipment, personnel profiles, etc.). Once these facilities are formally planned, an appropriate transportation network can be considered to connect them in a more efficient way. Thus, this could support the future planning for development of road infrastructure. In this context, a proposal based on the the capacitated vehicle routing problem (CVRP) can provide the routes and number of ambulances required to serve the communities within the network with the minimum time and distance.

Another opportunity to extend the present work is to gather information regarding the full services which can be provided at each facility. In example, although hospitals have the equipment to perform thoracic surgeries, the equipment is not suitable for brain surgeries. In such case, patients must be referred to top-level hospitals which are frequently located in large cities. The extended network must consider these cases.

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Optimization and process development methods in the production of sugar from Cuban sugar cane

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Keywords: Cuba economy, sugar production, process optimization, multi-stage collection, CORELAP method.
Abstract: Cuba's economy has fluctuated strongly due to COVID-19 and natural disasters. In addition, sugar production, which is Cuba's main export product, also fell sharply. In the absence of underdeveloped industrial technologies and digitization, Cuba currently has to allocate its resources with even greater consideration. That's why utilization and optimization of sugar production and transport can take advantage of its inherent potential and reserves. After presenting the history of sugar production and its current, mainly local, technology, we present three simple methods, which do not require very professional knowledge nor expensive software or hardware to optimise these processes. We recommend the establishment of basic collection points, which would operate as specific logistics centres, with the role of service provision and pre-production in addition to the collection. Also, the paper proposes a method that can be used to design layouts in 3D, making the current sugar production process more compact and efficient.

1 Introduction and literature research

Refined sugar plays a significant role in providing food for the growing world population. Compared to its weight, it has a significant energy content. Also, in the right hands, it is easy and sustainable to produce, and although excessive sugar consumption is considered unhealthy, it is part of our daily diet. Refined sugar can be produced from a variety of plants [1], but there are two proven sources in industrial quantities, which are ideal due to their high sucrose content: sugar beet (15-20%) and sugarcane (13-15%). In the continental climate of Europe, as well as in Hungary, sugar beet is the primary source of sugar, as it is the best source of sugar in our climate zone without any special maintenance. In subtropical environments, such as the one in which the Republic of Cuba belongs, the cultivation of sugar cane is more beneficial. In order to understand the sugar industry in the Caribbean region, we need to go a little deeper: where it comes from, what it went through and how it is currently. There are many sources available for this in the online literature databases. It is enough to enter the keywords "Cuban sugar industry", and more than 57,000 results are found in Google Scholar or 11,300 in the Elsevier database. One of the most significant works is the 1991 "The economics of Cuban sugar" by J Pérez-López [2], in which he describes the sugar production and trade activities in Cuba from the 1820s to 1988. He presents the plan-based sugar increase and their challenges in a little more detail in "The performance of the Cuban sugar industry 1981-1985" [3] or during the "Great Depression" [4] also in the 1970s [5]. The previous works did not write about the beginnings of sugar-making by slaves [6,7]. A large number of studies [8] and discussions [9] about the issues of the Cuban sugar industry have begun in the last 30 years. These three documents describe the recent restructuring of the sugar industry in 2002 [10] and its collapse in 2004 [11] and 10 years later [12]. As can be seen from most documents, the Cuban sugar industry is in decline, even though sugar is not only part of the Cuban diet [13], but a proven and important export item that is increasingly needed.

After the historical review, we focused on industrial applications and technical solutions from sugarcane cultivation through transportation to processing and delivery to customer, which helps us explore the problems and already proposed solutions for the entire system. The book "Cuban sugar industry: Transnational networks and engineering migrants in mid-nineteenth century Cuba" [14] provides a comprehensive picture of the technological and transportation solutions of the sugar industry in the middle of the 20th century. At this time, sugar was harvested primarily by hand or with very rudimentary machinery, transported by animal power and carts, furthermore, processed in various mills that used a lot of hand power and steam engines. The real development came in the 1950s,

when machines, tractors and trucks were delivered to Cuba from the USSR and the Eastern European block. Although the harvesting tools were not suitable (they were designed for sugar beets), they greatly boosted productivity. The railway to Cuba was one of the first to be built in the middle of the 19th century. By the middle of the 20th century, it completely covered the island, which was very important for the inland areas and productivity, but its development stopped after the 1960s [15]. These infrastructures and techniques exist to this day, unfortunately seeing very little development since then [16]. Unfortunately, many problems arise from the ageing infrastructure, technological machines and means of transport, which in themselves are significant, but in aggregate, represent a serious cost to the producers. One solution would be the automation of the industry [17], which, although the initial cost is high, would be very worthwhile in the long run. Also, the replacement of the old machinery fleet, which is already being investigated, for example, with new harvesting machines [18,19], can be a huge improvement and have long-lasting benefits.

However, there are opportunities for development within research and studies from several angles. In addition to the increasing fossil energy prices, several studies have been prepared on the energetic utilization of sugarcane as biofuel for vehicles [20] or also as bioethanol for direct combustion in power plants [21,22]. The alcohol industry is also a large receiving market, where new technologies appear both in the chemical effects of alcohols [23] and in the forms of distillation [24]. Sugar and its by-products are used all over the world and are in high demand [25]. Some of them can be used in the mill (for heating) or in the fields (as a soil conditioner and fertilizer). The rest (paper, chemical, alcohol and yeast industries and animal husbandry) must be stored, transported and sold [26].

There are those who see the growth in the control and optimization advantages provided by programming, such as controlling a multi-injection furnace with a fuzzy principle [27]. Simulation effectiveness studies have also been carried out in the sugar industry [28], and there are those who see the future in the effectiveness of a fully autonomous harvesting machines [29]. Unfortunately, Cuba is still lagging behind most countries in terms of IT innovations, digitization and access to the Internet [30], but it is constantly developing and is playing a major role in universities [31].

From the previous findings, it can be roughly deduced what the precarious situation is like from a logistical point of view in the field of the Cuban sugar industry. Unfortunately, the situation is not very promising, but there are those who see this as a great opportunity for development. Cuban industry must also reach the level of being an active part of global supply chains [32]. This was confirmed by several people not only with principles, but also with cost and productivity calculations [33] using Excel, solving scheduling problems [34] and studies [35]. In terms of infrastructure, the ports are in good condition and suitable for connecting to the supply chain [36]. In addition, the food distribution chain within Cuba was examined, in which sugar also plays a major role.

A life cycle analysis [37] was also created of the sugar industry, the produced sugar and its by-products, which evaluates the products and by-products from extraction to final usage and examines its environmental effects. The study establishes that the methods and machinery need to improve. An example of this is the new use of sugar industry waste [38]. Based on our literature research, it turned out that there are countless people studies the sugar industry and its history. However, we found very few, about 10 publications from the technological and logistical side, most of which were mentioned in this chapter. Of these, only 4 deal with the topic of logistics optimization, and within them, the emphasis is more on the optimization of transport in the existing system with the existing tools and infrastructure. In the following, we present methods that can be used to improve both external and internal logistics processes. But to understand the development potential, we first need to know the system we want to improve.

2 Process and products of sugar production

In order to reveal the problems and under-developed areas in the sugar industry, we also need to understand the process of sugar refinement. The Hungarian sugar industry is a very good example of this, as the process of sugar refinement is almost everywhere have the same process. Until the 2000s, Hungary was one of the main sugar producers in Europe, with 133 sugar factories operating in its territory since 1830 [39]. Unfortunately, since 2008, only 1 sugar factory in Kaposvár has been allowed to operate, the reason for which is the "sugar reform" signed upon joining the European Union [40]. This shows that Hungary's roots in sugar production go back quite a long time. The process shown in Figure 1 is also a modified diagram of the Hatvan sugar factory, and the technological steps described after it is also derived from it.

The subtropical environment of the Republic of Cuba in the Caribbean provides an ideal opportunity to produce sugar from sugar cane. Sugar cane is grown on large inland lands where the amount of precipitation is at least 60 cm per year. Then, it can produce up to 10-15 kg/m2 of sugar cane. Natural rainfall must be supplemented with irrigation, as it does not tolerate long droughts and cold wells. For these reasons, sugarcane can be grown for 6-7 months a year, which in turn means multiple harvests. The sugar cane does not need to be replanted every year. Instead of the cut stalks, a new shoot starts every year from the remaining stalks and root system, which greatly facilitates the cultivation. Due to the large monoculture and large fields fertilization is still necessary. 9% of potassium-based fertilizers are used for sugarcane cultivation every year [41].

The production of sugar is similar for both plants, after the formation of molasses it is completely the same.

Optimization and process development methods in the production of sugar from Cuban sugar cane
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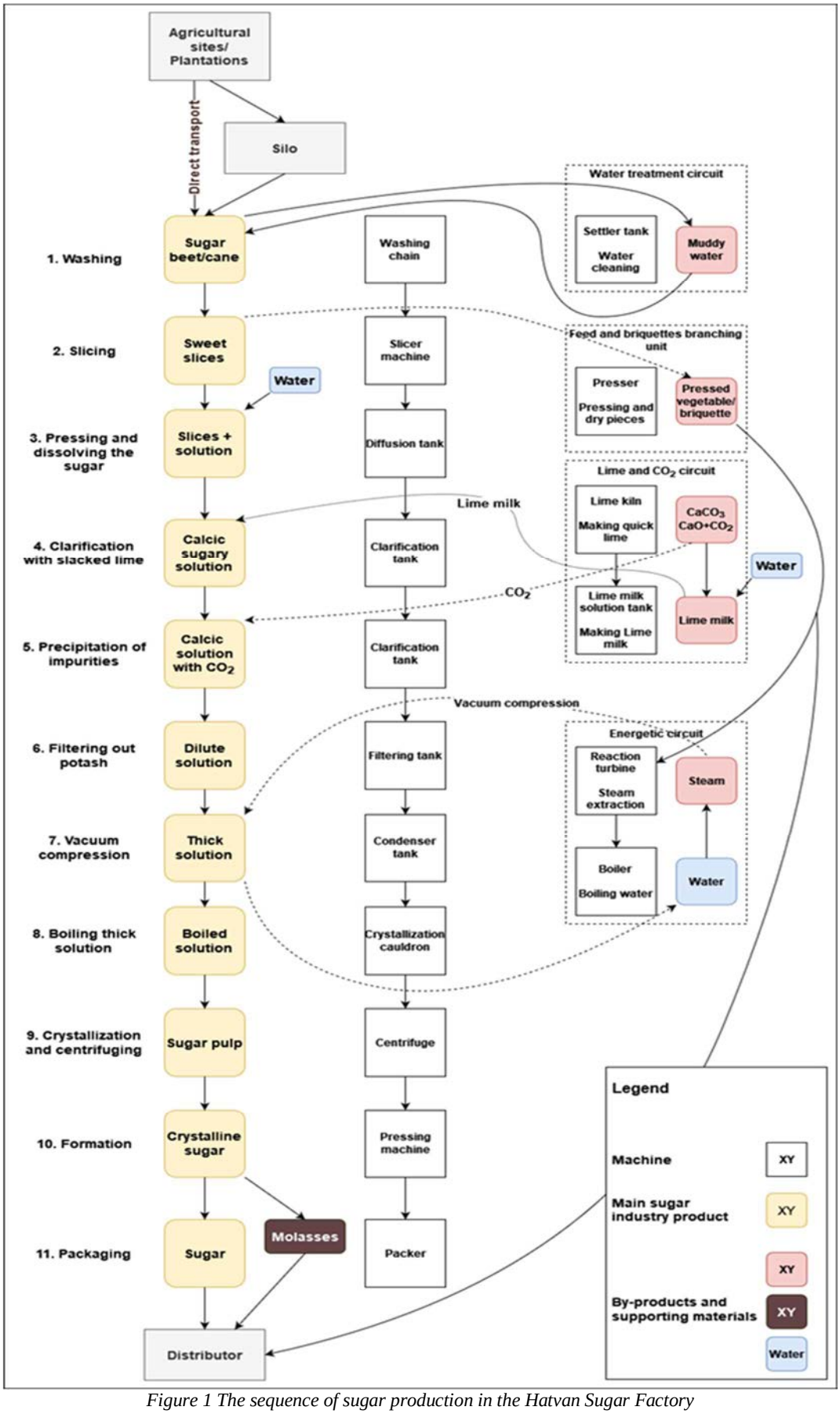


Figure 1 The sequence of sugar production in the Hatvan Sugar Factory

2.1 Technological steps of sugar refinement:

1. **Washing**: After harvesting and storing/transporting the beet/cane the very first operation is the washing process. The incoming beets/reeds move in bulk, and the washing begins as soon as they are unloaded from the wagons/silos/trucks with a high-pressure water jets. In the water stream addition to the plant there are also earth, stone, wood and other pollution must be captured. The washing operation is complex with multiple machines and filters. On the washing chain, the plant + water mixture is first carried forward by the gravity slope and then by water moved by a high-pressure compressor. At the end of washing, the flowing water is separated from the plant. The beet is taken to the slicer by a conveyor belt, and the wastewater is cleaned and then returned to the washing water cycle.
2. **Slicing**: The operation (called shaving for beets, splitting for canes) is basically the same as slicing vegetables at home. In the sugar factory, this operation takes place on a machine designed for large quantities and continuous operation. The slicing knives are attached to a disk located at the bottom of a cylinder. The descending disc rotates at high speed and slices the plants. The vegetables fed from above and pushes those located below into the rotating cylinder with rows of knives with its weight. The sliced parts fall onto a conveyor belt with a rubber belt or multi-segment belt, which transports the slices to the next location.
3. **Pressing and releasing the sugar**: The beet/cane enters a second water circuit. After the outer water circuit of the washing, this is the internal sugar factory water circuit. In this water circuit, the vegetable slices are first soaked in warm water so that the sugar goes into solution through the cell wall (diffusion). The place of action is the diffusion tank. The beet/cane slices leaving the process are first pressed, because the loosely structured material still contains a lot of sugar solution. In the case of beets, the pressed material is valuable feed, which is constantly transported, and in the case of sugar cane, feed, manure, and wax are produced from it, and then the remaining dry part is used to heat certain processes of sugar production.
4. **Clarificatio**n: The impurities in the sugar solution are precipitated, clarified (with lime milk) and fixed (with carbon dioxide). These operations are also carried out in large tanks. The lime milk is added to the solution in the first step of clarification. $Ca(OH)_2$ reacts with impurities. Even in the case of sugar cane, they use mainly lime milk for the clarification process, however, to extract the harder-to-access sugar even faster and more effectively, phosphoric acid is also added to the sugar solution.
5. **Precipitation of impurities:** Carbon dioxide (CO_2) is added to the solution. The carbon dioxide introduced into the solution reacts with the calcium hydroxide ($Ca(OH)_2$) and the impurities are precipitated into calcium carbonate ($CaCO_3$). The resulting precipitate can then be separated by filtration. Both lime and carbon dioxide are produced by heating limestone (traditional lime burning) in a separate factory: the lime incinerator, usually belonging to the sugar factory.
6. **Filtering out the lime sludge:** The lime sludge produced during clarification is filtered out of the solution. This operation is carried out on a filter press. By filtering out the impurities, a sugary water solution called dilute is created.
7. **Vacuum compression:** The slurry is heated with steam (carried by pipeline from the power plant connected to the sugar factory). When the hot solution enters a low-pressure space, it effectively evaporates part of its water content. The end product of the operation is the thick juice.
8. **Boiling thick juice:** Boiling takes place in huge containers. This operation involves additional water loss, and at the end of the process, the sugar solution becomes saturated and suitable for crystallization.
9. **Crystallization and centrifugation:** The crystals in the thick, saturated sugar solution are centrifuged. The centrifuge here is a rotating steel cylinder with a perforated surface. When the thick sugar paste is placed in the centrifuge, it partially cools, and the liquid part exits the perforated surface and the sugary solution is further thickened. Granules of sugar floating on the surface fall below, where they are caught in huge pans. The solution remaining at the end of repeated thickening (about three times) is molasses, which is also used in confectionary preparations (in the past), in fodder and in the preparation of syrups.
10. **Shaping:** The small crystalline material created is molded into the shape characteristic of the products. It used to be used in Hungary to sugar loaf. Today, it is mostly crushed into sugar cubes or refined into powdered sugar. However, most of the production remains in the form of granulated sugar. If we want to get brown sugar, we can achieve it by incompletely separating the molasses (impurity) or by adding it afterwards.
11. **Packaging the final products:** Granulated sugar households is placed in 0.5/1/2 kg mostly paper packaging or 15/25/50 kg paper-based bags or 1 ton big bags. Sugar cubes come in half-kilo or one-kilo boxes [39].

2.2 Main and by-products of the sugar industry

The main and by-products of the sugar industry have already been mentioned in the literature research, but the complete list and areas are shown in Figure 2. It shows us that nearly 40 different products can be produced by processing sugarcane, of which energy production plays a prominent role, which can be used for heating the furnaces and reactors in the sugar processing plant or release for sale. Fibers play a huge role in the paper industry, as cellulose or paper raw material, or as in the food industry

as Xylitol (sugar substitute). In addition, it places major role in the plastics- and construction industry, not to mention being used as litter or as a base in mushroom production. Many things can also be made from molasses. It is used in the alcohol industry: rum and other spirits are mainly produced for consumption, as disinfectants and ethanol. It can also be used to make feed for animals and fertilizer. When fermented, vinegar, acetic acid, citric acid, glycerol, lactic acid or yeast can be produced from it or with it. It also plays a major role in the chemical industry as a component of organic substances [25].

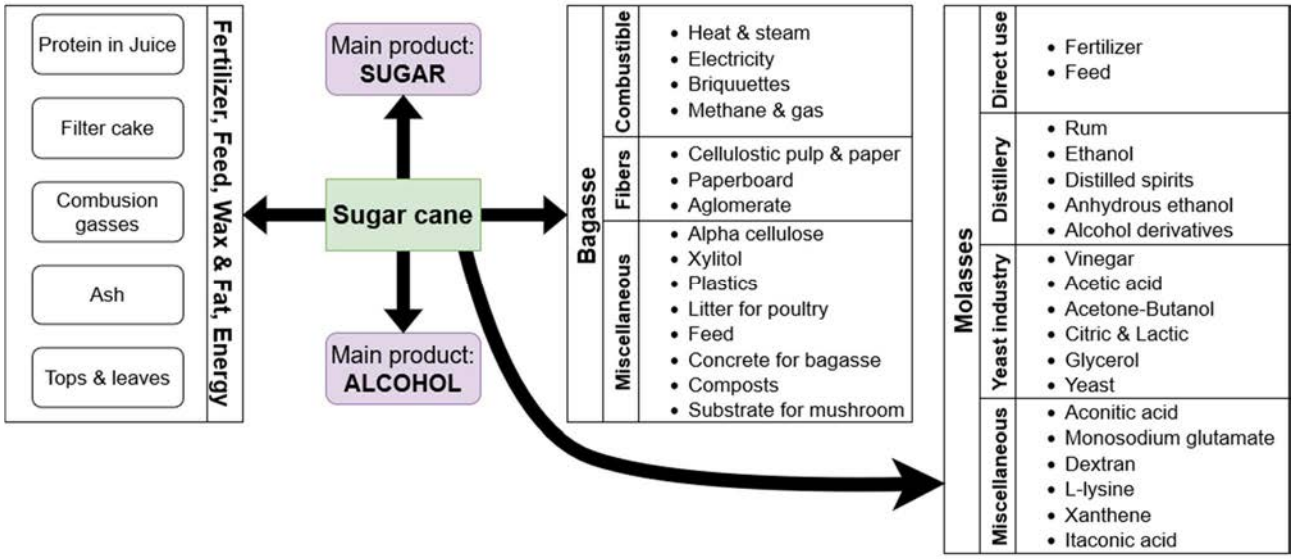


Figure 2 Sugarcane and sugar industry products and byproducts [25]

Now that we have become familiar with the processes, technology, infrastructure and production tools that are available or that are proposed by other researchers, we can see the system as a whole and make recommendations for it.

3 Optimization methods in logistics

One of the most obvious long-term cost reduction methods is to replace outdated tools and machines with newer, more modern and more effective tools. This is also true for the technology equipment that is in the sugar refinery, as well as for the means of harvesting and transportation. A truck made in the 1950s-1970s can consume 2-3 times more fuel than one made after 2000, not to mention the better working conditions and comfort in the newer vehicle. This is also true for hand-powered machines, tractors, harvesters, and for railway vehicles. Although this is a large investment and maintenance is also more difficult for newer machines, the payback time is expected between 5 and 10 years [19].

3.1 Location of one or more collection points from an area-based source

From a logistical point of view, a more serious task is the number of collection points to be established in a production area and the planning of transport routes and schedules for the harvested sugar cane to reach the sugar refinery. This can be seen through a specific example in the publication [33], in which they investigated the location of the collection points where the harvesting equipment collects the cut sugarcane and places it on the truck on several plantations in a larger production area. From now on, these collection points can be considered fix points since the area and yield rate of the lands will not change significantly in the future. As a proof of this, the authors created an algorithm written in Excel, which can calculate the ideal location of these points with various parameters, which also take into account the costs of transportation and collection, thus achieving an 8% fuel saving. A similar study was carried out by researchers in Iowa (USA), where they collect methods for gathering and transport challenges of local farming, including but not limited to the sugar industry [43]. In logistics, these are called the Center search or Multicenter search (defining and grouping of several locations) problem, in which the transportation work and transportation costs are usually the most significant components, but local features such as labor-, rental-, construction-, and infrastructure costs can also be taken into account. In the method of center search, the selection of the optimal location can be determined with iteration steps and ever-increasing resolution, however, in the case of multi-center search, clustering (group formation) is also involved, so this is a much more difficult task (NP-Hard) and there are no exact method for it. Usually, the location of several collection points is determined using heuristic methods and simulation [44].

3.2 Multi-stage collection and pre-processing method

The next cost reduction method is based on similar principles as the previous one, but it handles the problem one level higher. Instead of small local sugar processors, of which there are relatively many in Cuba, only the larger ones would operate; they are more efficient anyway; and the smaller ones would only carry out the first three steps. These would be the pre-processing plants, that collects, chops, and presses the received sugar cane. The press squeezes out the sugary juice and deliver it to the refineries in tankers (trucks/wagons). The process of this can be seen in Figure 3. Systems operating on a similar principle already exist in other areas [45]. In this case, a lot of idle traffic can be eliminated or reduced, since the vehicles full of sugar cane only have to travel part of the length. Squeezed and condensed juice requires much less space and mass than fresh sugar cane, but a vehicle with tanks is required to transport it. The less space and weight significantly reduce the transport work and cost, if a railway line is built between the pre-processing plant and refinery, the transport cost can be reduced to tenth up to twentieth of the original (truck) one. In addition, the pressed biomass, which rich in fiber, remains in the place where it is used for energy (burning) or fertilizing the crop fields. For other uses the pressed pulp also needs to be transported, but in a more compact way. Burning is necessary anyway to thicken the thin sugar-rich juice. The pre-processing plant would also be good, as it would reduce the amount of machines, which would give more attention to equipment where maintaining cost can be reduced and more effective ones could be bought from the same budget.

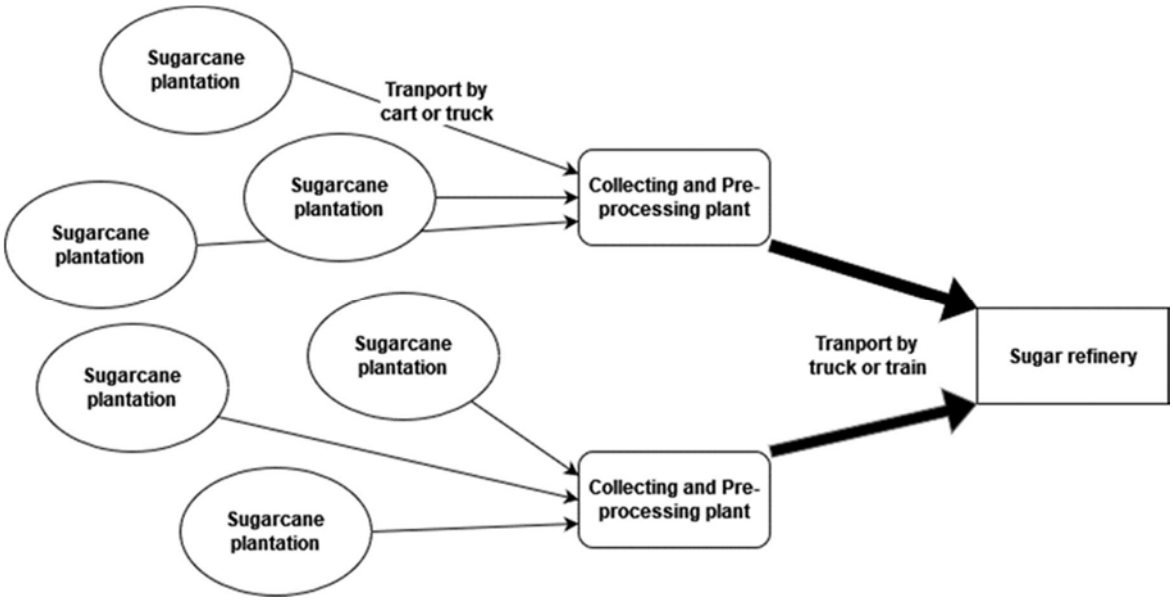


Figure 3 Multi-stage collection and pre-processing

3.3 Multi-stage collection and preprocessing method

Although the process, technology and machines of sugar refining are constantly developing, there are no major changes or variations in the process. The entire process forms a large chain, where sugar cane/beet enters the system from one direction and two important products (sugar and molasses) come out at the end of the process. For this, of course, other generally liquid or gaseous substances must be added; mainly water, lime milk and CO2; but the process, as shown in Figure 1, is very linear. In the case of sugar processing, most technology equipment is tank-like in which various physical or chemical modifications take place. These machines and systems are large, require a lot of energy and move large quantities. In order to primarily save energy (transportation and thermal energy), the basic principles of logistics must be taken into account when designing the refinery. Often, these machines and the entire system are located at ground level, typically arranged in a line or U-shape, which means easy access and less stress on the foundation. The layout at ground level is only permissible from the point of view of rental or purchase costs if the area on which we are building is considered cheap on an area basis, if this is not true, the upward expansion must be considered. Easy access at ground level also has the advantage for maintenance and cleaning, however, if this is not usually a problem and can be solved in another way, then the multi-level arrangement is preferable. In the case of a multi-level arrangement, the placement of machinery and technology equipment is more expensive, as a supporting structure must be created for it, and maintenance is considered more difficult due to the more compact arrangement and the work must be performed high up. However, multi-level facilities have a big advantage compared to ground-level ones, which is also true for liquids and bulk solids: once

the material has been lifted, it can move with the help of gravity without much energy input. This one-time, larger lift is generally much smaller than multiple smaller lifts and requires fewer machines, usually pumps. In addition, the outlet of the machinery and the inlet opening of the next equipment can be placed closer to each other, which is associated with the shortening of the transport routes, which in this respect results in less investment and less maintenance.

Unfortunately, there are not many well-developed methods in the literature for arranging the equipment of multi-level production, most people only listen to their inner intuition even at ground level. There are other heuristic methods, that uses heuristic algorithms, such as Genetic Algorithm for single floor layout design [46]. One of the most used single-level methods is the CORELAP (Computerized Relationship Layout Planning) method, which is an improved version of the MUTHER method [47,48]. Once the relationships between the various objects (machines, technology equipment, locations, etc.) have been determined using the MUTHER method, the relationship matrix is created from it, which is characterized (numbered) either by specific values (amount of material movement, work) or importance indicators. Based on the previous findings the connections between objects needs to be classified into 6 groups [49-51]:

- A: absolutely necessary connection; weight number: 4.
- E: especially important relationship; weight number: 3.
- I: important relationship; weight number: 2.
- O: okay (general) relationship; weight number: 1.
- U: unimportant (no connection required); weight number: 0.
- X: undesirable (contact must be avoided); weight number: -1.

We do this in the same way with the Multilevel CORELAP method, if we do not have specific numbers to describe the relationships.

The main steps of the Multilevel CORELAP method are as follows:

1. **Gathering the necessary initial data:**
   - defining the connection matrix of the objects to be installed, a clustered quadratic material matrix must be created [52]
   - the size of the available area,
   - the approximate area requirements of the objects to be arranged,
   - determination of the raster size (based on area or volume), which must be taken so that the smallest object is at least twice the raster size, but should not be fragmented too much, as the calculation demand increases.

2. **Ranking of objects:**

Following the CORELAP methodology, we add the weights (or other data) of the indicators in the relationship matrix for each object, the obtained values are presented, and the largest one is selected. It gets the highest rank of 1. As a next step, we add the relationship matrix with the weights again, but remove the already ranked object(s) from the calculation. The object with the highest value will be ranked 2nd, then 3rd, and so on. This process is repeated until all objects have a rank.

3. **Construction taking into account ranking and direction:**

Based on the received ranking and raster/volume requirement, we start placing our objects on a grid. The first rank should be in the middle of the middle level and we try to distribute the rasters so that most of them stay on the middle level, but if there are too many, we can flow over to the level above or below it. If possible, try to give regular shapes and do not fragment the objects if possible. As soon as the first one is taken down, the next rank can come, right next to it with all its rasters, if possible at the same level. After that, you can unpack all the rasters in a counterclockwise direction until the first rank has been circled around. After that, it is worth using the middle of the level below and above the first rank, then the main diagonals in the plane, then the main diagonals in space. Figure 4 helps to understand the directions in which 1 is the first-ranked place and then the other rasters should be placed in those directions in ascending order.

The description is not exact, it only gives guidelines as to where you should start when designing a layout. It is recommended to experiment with different raster group shapes and then check with the TCR value.

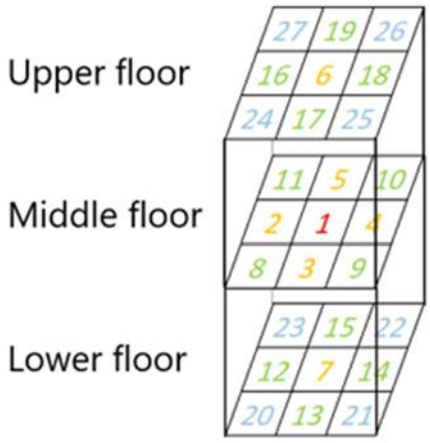


Figure 4 Direction of rastering in multilevel design

4. **Determination of TCR value, evaluation of floor plans**

The TCR (Total Closeness Rating) value shows how close the objects are to each other in the prepared layout,

which is obtained by adding the weights of all the objects adjacent to the object as seen from the relationship matrix. If an object is not directly related (they do not have a common side anywhere), then that object is not counted. The higher this number, the better the layout performs.

In the following example, we would like to demonstrate the operation and effectiveness of the method. The areas, connections and approximated material handling values came from a real-life sugar factory in Kaba (Hungary), which represents a sub-modern sugar factory which you can also see in Cuba. The connections (A…X) the type and power of connection and also takes into account the material flow in those connections. These connections are mostly approximations based on the opinions of experts.

Consider a system of 8 machines that we want to deploy. We know the floor space requirements of the machines and we have received how many grids they can occupy. Machines 2, 3, 5 and 6 can also be placed vertically, they do not have to be on the same level. The connection matrix, with the MUTHER methodical ranking, can be seen in the first segment of Table 1 (Machine-Machine grids). The Quantity of types counts how many connections has a machine with the same category of MUTHER classification. The total score calculated by multiplying each category's quantity with it's weights, which are shown in brackets. Based on this the first rank was given to the 5th machine based on the results.

Table 1 Rank 1 of Multilevel CORALAP example task

I.	Machine									Quantity of types (score)						Total score	Ranking	Raster/ Volume
		1	2	3	4	5	6	7	8	A(4)	E(3)	I(2)	O(1)	U(0)	X(-1)			
Machine	1		I	I	U	O	U	O	U	0	0	2	2	3	0	6		3
	2	I		O	U	O	U	U	O	0	0	1	3	3	0	5		5
	3	I	O		U	I	O	O	E	0	1	2	3	1	0	10		6
	4	U	U	U		O	O	O	X	0	0	0	3	3	1	2		12
	5	O	O	I	O		A	A	O	2	0	1	4	0	0	14	1	7
	6	U	U	O	O	A		I	O	1	0	1	2	2	0	8		8
	7	O	U	O	O	A	I		I	1	0	2	3	1	0	11		4
	8	U	O	E	X	O	O	I		0	1	1	3	1	1	7		7

Based on the description we did the ranking procedure and obtained the following ranking, which is visible in the Ranking column:

Table 2 Ranking of objects in Multilevel CORALAP example task

VI.	Machine									Quantity of types (score)						Total score	Ranking	Raster/ Volume
		1	2	3	4	5	6	7	8	A(4)	E(3)	I(2)	O(1)	U(0)	X(-1)			
Machine	1				U	O	U	O	U	0	0	0	0	2	0	0	6	3
	2			O	U	O	U	U	O	0	0	0	1	1	0	1	4	5
	3		O		U		O	O	E	0	1	0	0	1	0	3	2	6
	4	U	U	U		O	O	O	X	0	0	0	0	0	1	-1	7	12
	5	O	O		O		A	A	O	0	0	0	2	0	0	2	1	7
	6	U	U	O	O	A		I	O	0	0	0	2	0	0	2	5	8
	7	O	U	O	O	A	I		I	0	0	1	1	0	0	3	3	4
	8	U	O	E	X	O	O	I		0	0	0	0	0	1	-1	8	7

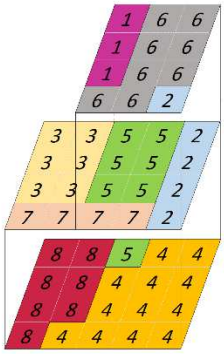
Next is the creation of the floor plan by rastering based on the description. We first made it one-story, as shown in the original method, which only came out so compact after several attempts and redrawings. Figure 5. also shows that the neighborhood value of the TCR is 32, where we leave out non-neighboring connections from the connection matrix. This value should be compared with another layout in order to get an idea of its effectiveness, however, the most significant categories A and E have all been preserved in the connection matrix, which indicates a very good layout.

TCR		Machine								Quantity of types (score)						TCR
		1	2	3	4	5	6	7	8	A(4)	E(3)	I(2)	O(1)	U(0)	X(-1)	
	1				U	O	U			0	0	0	1	2	0	1
M	2					O	U	U		0	0	0	1	2	0	1
a	3				U	I		O	E	0	1	1	1	1	0	6
c	4	U		U					X	0	0	0	0	2	1	-1
h	5	O	O	I			A	A		2	0	1	2	0	0	12
i	6	U	U			A				1	0	0	0	2	0	4
n	7		U	O		A			I	1	0	0	1	1	0	5
e	8			E	X			I		0	1	1	0	0	1	4
														Total TCR:		32

Figure 5 Single floor layout and outcome

Lastly, we also made the multi-level version. We solved the problem on 3 levels.

Its appearance and calculation can be seen in the following figure.



TCR		Machine								Quantity of types (score)						TCR
		1	2	3	4	5	6	7	8	A(4)	E(3)	I(2)	O(1)	U(0)	X(-1)	
	1					O	U			0	0	0	1	1	0	1
M	2				U	O	U	U		0	0	0	1	3	0	1
a	3					I		O	E	0	1	1	1		0	6
c	4		U			O		O	X	0	0	0	2	1	1	1
h	5	O	O	I	O		A	A	O	2	0	1	4	0	0	14
i	6	U	U			A		I		1	1	0	0	2	0	7
n	7		U	O	O	A	I		I	1	0	2	2	1	0	10
e	8			E	X	O		I		0	1	1	1	0	1	5
														Total TCR:		45

Figure 6 Multi floor layout and outcome

Due to the multi-level arrangement, this layout can have more neighbors than a single level, so the TCR in most times became bigger then in a single layout. In this case the TCR score was 45 and most important elements and connections were also preserved. The theoretical maximum of TCR score in this task is 65, if you add all weights except then negative ones, but this score most certainly can't be reached, due to the massive networking arrangement.

As we have already written, the process of sugar production is not as complex as the connection matrix of the system created as an example, it is much more linear, so simplifications can be applied. The vegetable to be processed must be placed on the highest level and the subsequent technological steps, such as shaping and packaging, on the lowest level. the intermediate steps with machines and fluid tanks can be given as dimensions or rasters to the method. With these facilitation we can easily achieve close to optimal results especially with the help of a computer program.

4 Results and discussion

As the literature research revealed, many people deal with the Cuban sugar industry, but most of these works are more historical, political, and statistical in nature. Very few works deal with the problems of sugar production and try to solve them with either a theoretical or an engineering approach. Our team in the field of logistics would like to transfer and implement this knowledge to the sugar industry environment, and for this purpose it has set itself the goal of familiarizing existing and new methods. In the work, we presented the cost-cutting methods and optimization procedures suggested by others, a multistage model for lowering transport cost, and a layout planning algorithm called Multilevel CORELAP method. Because the Algorithm is a new method, we provided an example for easier understanding.

5 Conclusions

The Cuban economy and sugar industry have recently been hit by major disasters. We cannot alleviate them, but we can change the processes, which are currently very wasteful of energy and resources. In the research, we recommend three main methods for optimizing the Cuban sugar industry and for better realize its inherent potential:

(1) Use the multistage model for lowering transport and storage costs. There should be local or regional logistic centres, with the primary purpose to handle sugar products and materials.

(2) Use these logistic centres near the sugarcane fields to decrease transport cost by lowering the heavy direct

transports length and pre-process the canes to lower their volume and mass for even lower transport needs.
(3) Use the layout planning algorithm called Multilevel CORELAP method, that can help to create better optimized factories, not just for the sugar industry.

With these models and other suggestion both external and internal logistics can be more efficiently for a sugar industry company, not just in Cuba.

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Evidence from United Arab Emirates universities on effective human resources policies for employee perceived performance
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Evidence from United Arab Emirates universities on effective human resources policies for employee perceived performance

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Keywords: human resources practices, Likert scale questionnaire, performance evaluation and planning, United Arab Emirates Universities, UAE.
Abstract: The current research is to ascertain the effect of human resources (HR) policies and procedures on employees. The study is based on the quantitative method. The employees at the United Arab Emirates universities are the selected audience. Google Forms was used to disperse the survey, where 100 responses were collected in this study. The questionnaire adopted a Likert scale of seven points. Tests such as factor loading, internal consistency, Convergent Validity (AVE), Discriminant validity, Coefficient of determination (R^2) and adjusted (R^2), Path Coefficient (β), and t-test through ADANCO were conducted. This research shows that performance evaluation of all other variables, such as compensation, promotion practices, training and development, and employee involvement in decisions, has a really beneficial impact on PEP. The current research helps universities to plan the practices of HR and increase the PEP of their teachers. This is because it has the potential to provide professors, academic leaders, and supervisors with fresh perspectives that will aid in the spread of knowledge and the efficient operation of the academic workplace. Employee turnover in UAE government agencies is affected by management style and a lack of employee empowerment, according to the study. There were signs that workers' distaste for centralized leadership influenced their desire to remain with their current employers. Many research papers have been done on this topic in developed countries. However, none of these studies has been accomplished.

1 Introduction

Human Resource Management is a significant rational and strategic consideration for the maintenance of any organization. It views personnel as essential to corporate objectives [1]. Organizations require human resources to perform various functions like improving employees' performance [2]. Many researchers have studied employee and firm performances that impact HR practices. Moreover, positive relationships were explored in diverse areas [2, 3]. Human resource management is critical for gaining an advantage over competitors. (Schuler and MacMillan, 1984). The performance of teachers in Pakistan's universities influences compensation practices. Promotion methods assist teachers in advancing and providing opportunities for professional development [4]. The United Arab Emirates' two biggest emirates are Dubai and Abu Dhabi, are known for being at the forefront of innovative practices in various industries. To fulfill the demands of the new knowledge economy, the government of Dubai established a coordinating agency in 2003 named the Human Resource Development Authority to collaborate with Dubai's educational institutions. This program has been essential in arousing nationwide curiosity about the benefits of learning at the personal, group, and corporate levels. For improved performance, large and small businesses have started valuing knowledge management and ongoing education. Worker involvement in decision-making affects employees" performance [5]. The term "performance" relates to completing a task or working. It occurs in the phase of the process, organization, and persons. The interdependencies between these will establish the organization's perspectives [6]. Today's workers appear to have less loyalty to their employers than in the past. The age-old contract between companies and workers based on loyalty in return for job security and fair treatment has broken down as a result of businesses' inability to guarantee employees' corporate career routes or the security of their employment [7]. Training and development methods contribute to the organization's ultimate aim. This benefits the organization and its individuals [8]. It has been found that most organizations in developing nations, particularly in Pakistan, do not install HRM systems [9]. They will build this culture, but growth will be gradual. Yet, as compared to the public sector, companies are implementing an HRM at a rapid pace. Many studies in underdeveloped nations failed because of a connection between performance on the job and human resource practices. Efficient HR procedures contribute to improved and modified employee behavior, which improves organizational performance. (Hornsby and Kuratko, 2003). Although human resource management (HRM) is essential for any company that wants to see the best possible results, not all of them put enough emphasis on it, which can cause HR resources to go unused [10]. This research pursues the effect of HR practices (repayment practices, promoting practices, performance assessment, education and improvement, and worker involvement in selection-making) on PEP. This study will assist the HR managers in public and private universities in

UAE. In developing HR techniques to guarantee high degrees of trainer effectiveness.

Although there may be a clear causal link between sustainable HRM and desired results [11], previous studies have only looked at statistical correlations between sustainable HRM systems and outcomes of the employees [12]. Thus, the prime objective of this research is to develop a deeper comprehension of the interplay between the various aspects that contribute to HRM's long-term viability and the maintenance of beneficial organizational outcomes. Considering every possible way, this study will enhance the topics related to personal development, performance consolidation, and worker involvement within satisfactory situations.

1.1 Literature review

HR practices

HRM has received much interest lately in developing countries' progress procedures [13]. There is little study bridging connection between HR behaviors and worker performance. Teclemichael Tessema and Soeters [2] checked out the relationship between the efficiency of the worker and human aid practices with the position of human resource consequences as a mediating issue [14]. The practices of Human Resources with eight numbered facts examined were recruitment and choice approaches, practices of placement, schooling strategies, profits control practices, employee efficiency evaluation practices, merchandising techniques, social security programs, pension plans, and grievance procedures [15]. Even though many authors have explored the topic, there is no consensus on the size or relationship between job contentment and productivity. Some studies with an initial consideration of identifying happiness and productivity are carried out [16]. However, there are many who maintain that contentment in the workplace directly impacts productivity, with the former causing the latter [17]. It has been argued that the causality should run in the other direction, with increased performance leading to happier workers.

Nonetheless, the perspective and data presented by Herzberg, Mausnes [18] are by far the strongest in this regard. They debated and discovered time and time again that workers' level of happiness in the workplace is what ultimately determines their productivity. Also, some more positive attitudes toward work typically lead to better performance [19]. On the flip side, a shift toward negativity at work often leads to a decline in productivity. Workers' output is heavily influenced by their degree of job satisfaction, as well as that of the organization as a whole, making it an essential concern for businesses [20]. On a broader scale, it's crucial to the success of the overall life satisfaction of working people. Sliter, Sliter [21] also found that a lack of job satisfaction has been hypothesized to be one of the primary causes of withdrawal, which can manifest in absenteeism, tardiness, labor turnover, and even illnesses and accidents. In contrast, dissatisfied workers have been shown to have higher rates of absenteeism and lower levels of commitment.

Jabnoun and Rasasi [22] evaluated the impact of both transformational and transactional leadership styles on employee engagement in United Arab Emirates healthcare facilities. Workers were chosen at random from six different UAE hospitals. A Multifactor Leadership Questionnaire was used in the study [23]. Employees who rated their leaders high on all three dimensions of transformational leadership (charismatic appeal, intellectual challenge, and personal relevance) and greater levels of work satisfaction were indicated by those who received the contingent incentive of transactional leadership. Medley and Larochelle [24] investigated the impact of different nursing leadership types on employee morale and work satisfaction. Bush, Michalek [25] identified that Community hospital staff nurses' perceptions of transformational leadership and job happiness were measured using this study's Multifactor Leadership Questionnaire and the Index of Work Satisfaction. The research found evidence of an acceptance of transformational leadership among hospital staff nurses. This results in fewer sick days and a general increase in awareness of appropriate workplace conduct.

Compensation is among the most explored HR practices [9]. Employee performance is connected to HR procedures. For illustration, Olaosebikan [26]assessed the outcomes of three HR compensation, practices, performance, and promotion assessment on the effectiveness of non-public universities instructors in Peshawar, KPK, Pakistan. He observed that repayment, promotion, and performance evaluation have an excellent connection with perceived performance. Hashim, Rafi [9] assessed the outcomes of 3 HR practices; repayment, advertising, and performance assessment at the same university. He found some unbiased variables, reimbursement, promotion, and performance assessment, positively connected with understandable performance. Educators may now replicate the flow of their staff with the use of a variety of software solution tools and technologies made possible by recent technological advancements [27].

Employee performance

The employee's conduct is required to determine the employee's performance [10]. One of the authors, Yiing and Ahmad [28] found that Employee performance is a collection of behaviors that contribute to achieving company objectives. Performance is how people behave rather than what they produce in an organization [29]. Perceived performance refers to an organization's success, according to Yiing and Ahmad [28], determined by the general perception of the employee's share of their behavior. Declarative knowledge, motivation, and procedural knowledge are significant in the case of employee performance [30].

Compensation and PEP

Compensation is the compensation given to employees for services to achieve organizational goals. Sajid and Nauman [31] found that recognition at the social level improved performance at a specific task by 17%, financial rewards by 23%, and feedback by 10%. Compensation improved employee performance by 45%, according to the findings. Shakir and Zamir [32] looked into considered effect regarding incentives upon the performance of secondary school teachers. The results revealed a link between futuristic rewards and performance. Zanko, Badham [33] considered no hyperlink between performance and pessimistic rewards.

Promotion practices and PEP

Promotional consideration is given when a person is elevated from one positional sense of employment to another. It comes with a more excellent wage package and more work duties. Employees are more motivated when given the necessary resources to meet their goals [34]. According to the authors Teclemichael Tessema and Soeters [2], Promotional activities impact PEP. If businesses wish to improve their performance, they must provide promotional possibilities to their staff [35]. Zulfqar, Bilal [36] considered the facts of promotion methods moderately influence PEP. Sajid and Nauman [31] explained that promotion methods benefit PEP and promotional tactics. The availability of a written operational policy and seniority preference are all factors to consider.

Performance evaluation practices and PEP

Evaluation of Performance is based on the perceptions of friends, supervisors, subordinates, managers, or even people themselves. It contributes to increased production because it supervises the employees. Evaluation and improvement of productivity rely on effective performance management systems [37]. According to Shahzad, Rehman [38], evaluation methods used in the pharmaceutical industry businesses impact PEP. Sajid and Nauman [31] found that performance evaluation processes, the availability of written and operational performance evaluations, feedback, management recognition of the value of assessment, and competent performance assessors all play a crucial role in improving employee performance.

SOHRM practices

Strategic HRM is essential to spreading the LO concept since it introduces cutting-edge HRM techniques and reward systems to encourage organizational growth and development through knowledge sharing. Some of the authors, like Boohene [39], Siddique [40], illustrated that the term "learning organization" serves this purpose. Human resource management (HRM) strategies can encourage workers to improve their abilities and put those improvements to use in ways that benefit the company's performance objectives. Tangeman [41] evaluated that these HRM strategies include selection, compensation, performance evaluation, and career advancement. Strategic human resource management practices affect not just the willingness of workers to learn new things but also the eagerness of current workers to teach others [42, 43].

Human resource management has undergone a dramatic transformation over the past three decades, going from a bureaucratic "people management" focus to a more strategic "business management" focus. Consequently, senior leadership increasingly sees human resource management as a strategic partner [42, 44]. Wirtenberg, Harmon [45] agree that HR is now playing a more central strategic role; one of its main objectives is to ensure that all the initiatives it oversees align with the company's stated aims and values. According to Legge [46], HR managers need to create and pursue innovative policies in employee selection, compensation, performance evaluation, and career development in order to integrate the HRM function with the organization's goals of self-renewal and transformation through continuous learning [47].

Training and development and PEP

Arulrajah, Opatha [48] precepted knowledge, understanding, methodologies, and practices are all considered by the training facts and development. Training and development are crucial in HRM because they enhance individual, team, and organizational performance [49]. Tahir, Yousafzai [8] checked the effect of T&D on the skills and attitudes examined to link them to employee performance levels in Pakistani banks. Kalyani and Sahoo [50] highlighted that most personnel agreed that T & D greatly impacted their job know-how, work satisfaction and quantity, practical abilities, motivation, and loyalty. All related to performance in a helping route. Imran and Tanveer [49] discovered that training and development give employees opportunities for career advancement, thus improving the organization's efficiency. Employees, yet, are an organization's resources and assets. Those qualified will outperform the incompetent and untrained.

Albrecht, Bakker [51] considered some researchers at the precision of micro and meso levels to see the global Talent Management and Development (TMD) process as an everlasting, steady notion that deserved investment. Kesler [52] proposed that dealing with global TMD necessitated a consistent, continuous bondage that included discipline, decisiveness, and taking appropriate risks. Kim and McLean [53] argued in favor of a TMD systematization on a global scale, in which practitioners considering HRC would lead and have well-defined duties and responsibilities.

They hypothesized that a globally standardized approach to TMD would produce organizational and individual benefits, provided that the system considers the various cultural norms. Schuler and Jackson [44] Multiple factors, such as (a) managers' lack of experience with TMD, (b) varied organizational structures, (c) managers' lack of adoption and engagement in TMD, (d) employees'

lack of performance, (e) human resources' lack of expertise in dealing with TMD challenges, and (f) upper management's lack of time investment in TMD, were identified mentioned researchers as impediments to global TMD initiatives. Dirani, Bowman [54] also addressed these limitations for any worldwide TMD strategy to succeed the facts about participation of workers in policymaking and PEP.

Akuoko, Dwumah [5] found that employee participation in decision-making impacts worker performance. Cooper, Bottomley [55] outlined three distinct approaches to teacher leadership: the "every teacher is a leader" model, the "lead teacher" model, and the "many leadership positions" model. One definition of a lead teacher is "advising teacher," while others include "helping teacher" and "staff development associate." The head teacher is responsible for collaborating with other educators to develop and execute high-quality pedagogical practices. In education, there are a wide variety of leadership positions that may be filled, and the various leadership roles model accounts for all of them. It also includes roles such as mentor to new teachers, teacher trainer, member of the school's governing body, and member of a university team in charge of planning, coordinating, and supervising preservice teachers. The various leadership positions paradigm is the result of combining these functions.

Graphical representation

Figure 1 shows a conceptual framework. This study includes two variables which are HR practices and PEP. Human resource practices are the independent variable, while PEP is the dependent one. The five HR practices included are Compensation, Performance evaluation, Promotion practices, Training and Development, and Employee involvement in decision-making. This research shows that the practices of HR have a crucial impact on PEP and can lead to enhancing PEP in the universities of the United Arab Emirates. During the quantitative phase, a questionnaire designed by researchers was sent out to all of the schools in the city of Al Ain and then collected by graduate student researchers two days later. The questionnaire had a total of 35 questions, all of which were taken from previous research on teacher leadership techniques. The participant's demographic information was gathered in the first section of the questionnaire, and the next section of the question-related facts contained statements that investigated the participants' level of agreement considering the leadership practices of the teachers. Both sections of the questionnaire were divided into two parts. Responses were rated on a seven-point Likert scale, considering four of them, with four representing strong agreement and always, three representing agreeing often, two representing disagreeing rarely, and one representing strongly disagreeing never. A group of specialists comprised of four teaching staff at the United Arab Emirates University, especially the College of Education members, examined the questionnaire to determine its validity in terms of its content and appearance. Transcripts of the interviews were sent to us, and we read through them in turn. We jotted repeated words or phrases in the document's margins considering various down notes and descriptive codes. Following that, we conceived of many classes or topics for these codes. Quotes from the interviews were used to illustrate each theme and provide support for them. To provide answers to the research questions, we went over the themes and discussed them.

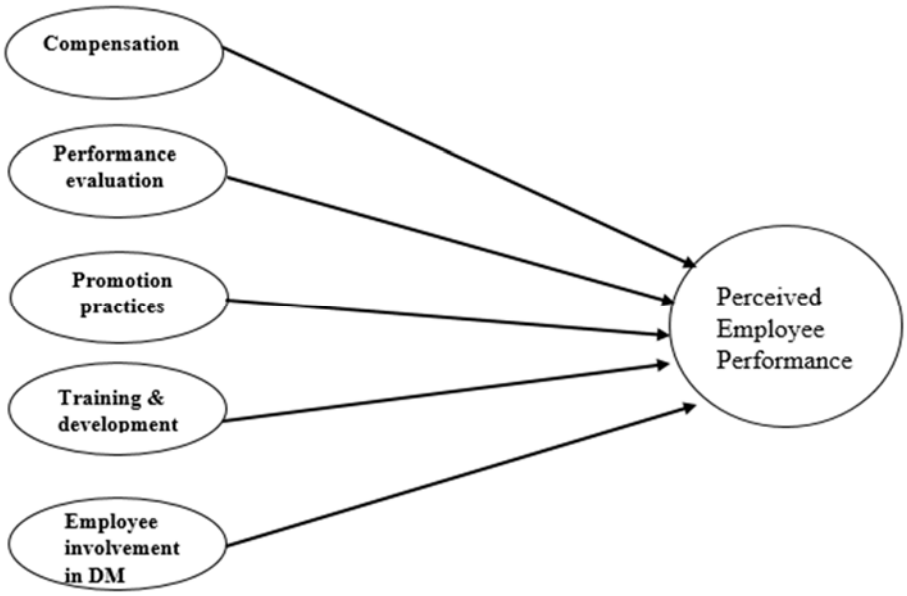

Figure 1 Conceptual framework

Research hypotheses have been depicted in Table 1.

Table 1 Research hypotheses

Numbers	Hypotheses
H1	Compensation Effects Perceived Employee Performance.
H2	Employees' Perceptions of Their Own Performance are Affected by Performance Reviews.
H3	Promoting practices affect Perceived worker performance.
H4	Training and development affect Perceived Employee Performance.
H5	Employment involvement in decision-making affects Perceived Employee Performance.

2 Methodology

The quantitative method is one of the most effective methods for understanding this research. The research intends to understand the highly impacted practice of HR by practicing PEP. It includes respondents with similar characteristics, but from different places, so the testing method is cross-sectional [3]. University employees of the United Arab Emirates are the target audience. The adapted questionnaire is utilized to fit the need of the research better. The research's participants provided one hundred responses, which were gathered. Non-probability sampling techniques, such as convenience sampling, were also used in this investigation. In convenience sampling, a sample from a population subgroup is taken. This kind of sampling is suitable for pilot testing. There are two sections in the study's questionnaire. The initial section included five questions about the demographics of the respondents as gender (male and female), age (22-50 and above), qualification (graduate to doctorate), and designation (lecturer to professor). The second section of the questionnaire included questions related to the independent and dependent variables of the study. The second section focused on the research variables and their associated questions. Five questions were about compensation, four related to performance evaluation, and two were about promotion practices. There were two questions about training and development, two about employee involvement in decision-making, and five about PEP. The responses were compiled into a 7-point Likert scale, with one mentioning "strongly disagree" and seven mentioning "strongly agree".

The primary data used in this study was gathered via a customized questionnaire and replies from university employees. The use of literature, e-books, e-journals, and e-articles allowed for the collection of secondary source data. Google Forms were used to collect the data. A total of 100 replies will be evaluated, ADANCO was utilized.

3 Result and discussion

Reliability and validity

Factor loading is used to identify which factor influences each variable most. 0.4 - 0.7 is the acceptance criterion 0.7. Its value is 0.7 and above, which indicates that the factor considerably influences the variable [56]. The factor has a weak influence on the variable if the loadings are near zero. According to the model, no factor loading value is below 0.4, indicating indicators' impact on each variable.

Table 2 Factor loading (FL)

Employee Performance		Compensation		Performance evaluation		Promotion practices		Training and Development		Employee involvement in DM	
Indicators	**FL**	**Indicators**	**FL**	**Indicators**	**FL**	**Indicators**	**FL**	**Indicators**	**FL**	**Indicators**	**FL**
EM1	0.8467	C1	0.8543	PE1	0.8447	PP1	0.9555	TD1	0.7762	EI1	0.9286
EM2	0.7822	C2	0.8097	PE2	0.8655	PP2	0.9230	TD2	0.9328	EI2	0.9010
EM3	0.9207	C3	0.8464	PE3	0.8756						
EM4	0.8232	C4	0.7741	PE4	0.8891						
EM5	0.7964	C5	0.7341								

Internal consistency

Alpha Cronbach's alpha value greater than 0.6 is a reliable and appropriate index. The value of Cronbach value is low when it is below 0.6. Alpha Cronbach's coefficient range is 0.60 to 0.80, which is acceptable (Khidzir, Ismail, and Abdullah, 2018). Cronbach alpha's value in this research is between 0.6 and above, which shows the reliability of this research.

Table 3 Cronbach's Alpha

Construct Cronbach's alpha(α)	
Employee Performance	0.8906
Compensation	0.8634
Performance evaluation	0.8922
Promotion practices	0.8689
Training and Development	0.6638
Employee involvement in Decision making	0.8065

Convergent validity (AVE)

The consistency of the constructs with one other is assessed using the Average Variance Extracted (AVE) approach. The ideal range for AVE is 0.5 or higher (Fornell and Larcker, 1981). This study's AVE values are higher than 0.5, indicating better consistency.

Discriminant validity: Fornell-Larcker criterion

Assess the paradigm of shared variance among the model's hierarchy of latent variables. Fornell and Larcker [57] criterion has been utilized. This criterion uses the Average Variance Extracted (AVE) and Composite Reliability (CR) to assess the measurement model's convergent validity [58].

Table 4 Convergent Validity

Construct	AVE
Employee Performance	0.6977
Compensation	0.6480
Performance evaluation	0.7550
Promotion practices	0.8824
Training and Development	0.7363
Employee involvement in Decision making	0.8371

Table 5 Fornell-Larcker criterion

Construct	Employee Performance	Compensation	Performance evaluation	Promotion practices	Training and Development	Employee involvement in Decision making
Employee Performance	0.6977					
Compensation	0.7337	0.6480				
Performance evaluation	0.5241	0.7673	0.7550			
Promotion practices	0.3977	0.5155	0.7775	0.8824		
Training and Development	0.4425	0.5009	0.5800	0.4299	0.7363	
Employee involvement in Decision making	0.4892	0.5933	0.6941	0.5282	0.5733	0.8371

Coefficient of determination (R^2) and adjusted (R^2)

R^2 measures the consideration of an endogenous variable that defines the independent construct. Its values range between 0 to 1 depending upon the type of research [59]. The mutual effect on the latent variable will be weak to be assessed from a practical perspective if the values of R^2 coefficients and adjusted R^2 are less than 0.02 [59].

Table 6 depicts the value of an endogenous variable. Proposed Coefficients of determination (R^2) and Adjusted (R^2) are above 0.02, which states that mutual impact in an outstanding variable is not weak.

Table 6 Structural model

Construct	Coefficient of determination (R^2)	Adjusted (R^2)
Employee performance	0.7650	0.7324

Path coefficient

The beta value path coefficient represents the relationship between the two constructs. The correlation has a range of -1 to +1. The correlation is shown as -1 for a negative correlation, +1 for a positive correlation, and 0 for no association [60]. Table 6 shows the correlation between HR policies and promotional effectiveness. Pay Per Employee (PEP) has a positive and statistically significant (R = 0.9568) relationship with compensation. PEP and performance reviews have a weak negative correlation (R=-0.5281). The correlation between promotional methods and PEP is favorable and statistically significant (=0.2147). There is a statistical and positive value of a significant link between T&D and PEP (R=0.1474). Employee participation in DM is positively related to performance evaluation performance (PEP) (R=0.1348).

Table 7 Path coefficient (β)

Independent variable	Dependent variable
	Employee performance
Compensation	0.9568
Performance evaluation	-0.5281
Promotion practices	0.2147
Training and Development	0.1474
Employee involvement in Decision making	0.1348

The path coefficient (β) H1, H3, H4, and H5 are accepted. Compensation, Promotion practices, Training and Development, and Employee involvement in Decision making positively impact PEP. However, H2 considers

they are unaccepted, while Performance evaluation is insignificant in influencing PEP.

Graphical representation of the model

The graph illustration for this study divides some of the evaluation factors into employee performance, where the value of R^2 is 0.765, and presents every element by ADANCO. The considerations for evaluating facts are compensation, performance evaluation, promotion practices, T&D, and Employee involvement in DM. Every consideration has its own R^2 value, and the cumulative one suggests that it is a united satisfier one by the ADANCO modelling.

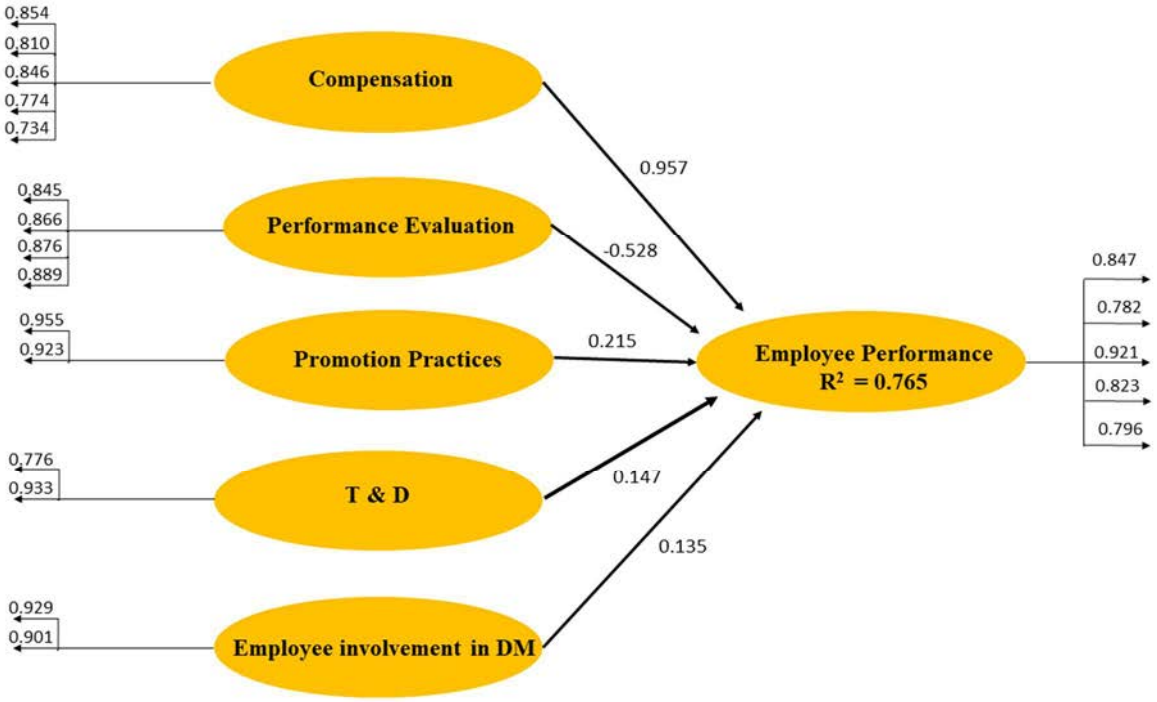

Figure 2 Model through ADANCO

Personal factors

Qualitative research has uncovered two key characteristics that encourage or discourage educators from assuming leadership responsibilities. These factors shaped teachers' definitions of teacher leadership and their comfort levels with taking on leadership roles. A minority of the educators we spoke with had a firm grasp on the magnitude of their leadership potential. However, most had never heard of teachers in a leadership capacity. Finally, knowing more about the inner workings of the university is helpful for assuming leadership roles. This happens when educators step up and offer to take charge. As a rule, this occurs with freshly employed educators or native English speakers hired to teach in colleges.

The aim of this mixed-methods research was to investigate the phases considerable in which educators in the United Arab Emirates are using leadership, as well as the variables that have either encouraged or discouraged them from becoming teacher leaders. While the numbers painted a positive picture of school leadership, the qualitative data painted a quite different picture. The quantitative findings showed that both male and female teachers regularly took on leadership responsibilities in the classroom, perhaps because principals of secondary schools increasingly demand that educators work together to develop and implement strategies for school improvement. The qualitative evidence confirms this finding, as colleges have long been the target of several initiatives to modernize and reform them. As part of the new college reform, it is not unusual for faculty members to take on leadership positions in classroom instruction and student learning. One such example is the requirement to work together to organize their lessons and extracurriculars.

Most teachers believed that their "leadership" responsibilities were best served by focusing on classroom instruction and encouraging student improvement in academic performance. We found that the term "teacher leadership" was rarely utilized in the schools we observed. Many people we talked to had no concept of "teachers as leaders" and only connected the term "leadership" to authoritative titles. Perhaps this is because they realized their work was about education, not leadership, as Fairman and Mackenzie [61] discovered. Our findings are supported by the fact that not a single educator we spoke with included "coaching" or "mentoring" among the duties they felt instructors should do. To a similar extent, Xie and Shen [62] discovered that the vast majority of educators

believed their leadership responsibilities ended with the classroom.

According to the numbers, most school administrations back teachers who take on leadership roles in the classroom. Teachers were encouraged to work in teams, and principals were confident in their talents, giving each group a leader and providing ongoing feedback. Qualitative data revealed numerous roadblocks for educators to take on leadership responsibilities. Yes, administrators frequently pushed for collaborative efforts among teachers. However, there was a problem with the equitable distribution of leadership opportunities because most college principals favored a select few teachers for promotion to administrative positions. This information demonstrates that allocating leadership duties in colleges is not as equal as the questionnaire responses suggested.

4 Conclusions

Many developed countries have analyzed the effect of HR practices on employee-perceived performance. That is why this research explores the impact of HR practices on the PEP of the universities of the United Arab Emirates. The universities of Pakistan are currently adopting HR practices to enhance performance of employees. The goal of this research is to identify whether HR practices, in this research, have a significant impact on PEP and whether they are practiced in the universities of the United Arab Emirates. The purpose of this study is to provide a framework for consolidating and analyzing the interplay between various factors. Many factors, including as job satisfaction, HR practices, leadership, retention, organizational culture, and labor markets, are available in the literature and may be used to construct the theoretical framework. The relationship between leadership, work satisfaction, and organizational commitment is the fundamental insight offered by this study paradigm. The secondary contribution is research on employee turnover in relation to human resources practices and the economic climate. The finding of this research depicts that factor loading affects this study's variable, which shows that the universities of the United Arab Emirates have adopted HR practices to some extent. Compensation, Performance evaluation, promotion practices, development and training, and Employee involvement in the DM have been considered independent variables. Their relationship with the dependent variable PEP according to path coefficient (β) is significant and positive, except for performance evaluation and PEP. So, in the view of this research, the organization should allow the employee to share their perspectives. Then consider those views while DM and motivate the employee by giving them a financial reward in the form of Compensation, Training, and development, encouraging them with promotion to achieve their perspective goal and all these practices. By improving the PEP and guiding the universities toward success, a better reputation, and more output, it will be possible to raise the perception of the institutions' value.

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Lean 4.0 in port management: an alternative to support the development of the circular economy in the sector
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Lean 4.0 in port management: an alternative to support the development of the circular economy in the sector

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Keywords: circular economy, lean port terminal, port management, Lean 4.0.
Abstract: Ports and terminals are directly related to world economic development due to international trade. In this sense, port management has expanded actions in terms of sustainability and mainly linked to circular economy (CE). The port environment is not alien to society's developments and for that it needs to improve its efficiency and operability, reducing the waste of time, processes and waste generated within it. In this context, this research links the Lean 4.0 concept with the circular economy as an alternative for the development of the port sector. The study is based on highlighting the challenges and advantages of implementing CE in ports through Lean 4.0. To achieve the objective of this research, a literature review was carried out based on the Sytematic Research Flow - SSF method proposed by Ferenhof and Fernandes (2016), followed by a content analysis based on Bardin (2011). Based on the findings, it was possible to list the key elements linked to Lean 4.0 correlated with the circular economy to stimulate the sustainability of the port sector. It was identified that Lean 4.0 presents itself as a simplifier for the implementation of the circular economy culture, since it enables the alignment of people to identify waste, stimulates innovation and the development of a culture aimed at continuous improvement in the sector.

1 Introduction

The advance of international trade and its expansion are important factors for the economic growth of countries [1]. Seaports have an impact on the economy of the port region and the environment in which they are located, they are the gateway to international trade. A large portion of international trade is handled by seaports [2]. In this way, policies aimed at the port system play a role directly related to the economic development of countries [3]. The port sector presents itself as one of the major obstacles to international trade in Brazil. The need for adequate infrastructure implies significant investment to ensure that cargo can flow through ports and terminals [4].

With the increase in cargo movement in ports, it becomes even more necessary to preserve the ecosystem and the search for resources that reduce environmental impacts. Research shows that activities related to this subject in ports are low, in order to develop initiatives focusing on environmental challenges, followed by economic ones, this article elucidates positive contributions about Lean 4.0 in the port circular economy as an alternative for the development of management port [5].

The circular economy (CE) has become increasingly evident in the political sphere, after the release of the plan that describes actions for the circular economy published in 2015 to the Green Deal, launched in 2019 by the European Commission, and the circular economy representing the port authorities belonging to the Member States of the European Union, legitimizing ports as components of great importance when it comes to achieving sustainability goals [6].

Based on the above, this article seeks to link Lean 4.0 as a tool to foster the circular economy for the development of management in ports. The Lean Port Terminal concept comprises a management system based on the Lean Thinking concept, which comprises principles, tools, methods and management practices for continuous improvement, increased earnings and elimination of waste

in the port sector from the perspective of the customer [7]. The elimination of this waste results in operational processes that are more focused on quality, productivity and low cost, creating a basis for operational excellence and ensuring competitiveness [8].

With the implementation of this management system, it is possible to create proposals aimed at ensuring the ability to compete, maintain, manage and operate the entire port system based on the application of the Green Deal (GD) using circular economy resources [5].

In this way, this research links the Lean 4.0 concept with the circular economy as an alternative for the development of port management.-We hope to answer the following research question: How can the Lean 4.0 approach support ports and terminals in the context of the circular port economy? Then, this study is based on highlighting the challenges and advantages of implementing CE in ports through Lean 4.0. To achieve the objective of this research, a Systematic Literature Review - SLR literature review was carried out based on the Systematic Research Flow - SSF method and a content analysis.

The main contribution of this article is to address a topic that is still little discussed in the port environment, as well as to present alternatives to maximize gains in terms of port sustainability with the adoption of Lean Thinking and the circular economy. By combining these two approaches, it is possible to encourage sustainable management for ports, in order to provide operational efficiency and reduce the environmental impact with the implementation of environmental management systems and certifications related to sustainability, based on Lean management. together with technologies arising from industry 4.0. Lean 4.0 allows the adoption of cutting-edge technologies and equipment that promote energy efficiency and the reduction of emissions, fostering the circular economy through the implementation of reuse programs, reduction and recycling of materials, investments in research and development of new technologies and solutions to promote the circular economy and port sustainability.

2 Research background

Lean emerged in Japan, in view of the observation by the Toyota automobile industry that it would not be possible to fund the reconstruction of its facilities, which were dismantled in the Second World War, and even in this scenario it was possible to manufacture a wide range of products and reduce defects, inventories, investments and workers' efforts [9].

One of the pillars of Lean is addressed as the human factor, successfully challenged mass production practices, providing greater flexibility of production systems and processes, resulting in products and supply chains, with less waste [10]. The elimination of waste is guided by five basic principles established in the book Lean Thinking, by Womack and Jones (1996):

1) Specify value: identify which activities add value;
2) Map the value stream: create a visual representation of all activities to easily identify waste;
3) Flow: products and services must move immediately between activities that add value;
4) Pull: customer demand should dictate the flow rate;
5) Perfection: improvement must be continuous

Lean brings benefits for organizations to be more competitive, as it creates value for customers by eliminating all waste from activities and obtaining lean processes with high economic efficiency. Due to this there has been a wide adoption of Lean practices in different sectors and scenarios in the last three decades [12-14].

Through research in manufacturing companies in developed countries it is possible to conclude that Lean can be a prerequisite for digital technology using technologies in production [15]. In this context, Industry 4.0, which emerged in Germany, with the idea of an integrated industry and expanded to other countries in the world with different government initiatives as a global technological trend, can help in the prerequisites of Lean [16].

Industry 4.0 is characterized by digital transformation and is considered the fourth industrial revolution. The core of this environment is the integrated use of technologies, such as: Internet of Things, Cybersecurity, Augmented Reality, Big Data – analysis and interpretation of large volumes of data, Robotic Automation, Additive Manufacturing, Simulation, Systems Integration, The Cloud - Managing Systems in the Clouds [17].

Taking the Technische Universität Dortmund study as a reference, there are four key components for the realization of Industry 4.0 [18]. These elements are classified as Cyber-Physical Systems (CPS), Internet of Things (IoT) and Internet of Services (IoS) and Smart Factory [19]. With Industry 4.0 components, such as the use of intelligent transport equipment in order to implement a system to gather materials driven by demand, it shows when a certain component is ready to be collected and only authorizes transport when there is demand. With this, there is a reduction of waste, taking employees out of an unnecessary activity [20].

The automation associated with Industry 4.0, questions regarding the integration between approaches and the role of Lean in this industrial revolution are ongoing. As an example, current and future state mapping is available on mobile devices, enabling human-machine integration. As all the data is stored in the “cloud”, the information can be shared between the different departments, enabling fast-time requests for spare parts, dynamic scheduling of maintenance activities and transparency of the information generated. The results show that Industry 4.0 tools can help Lean achieve the objectives [10].

The general objectives of Industry 4.0 are to allow improvements in the value streams of companies, addressing issues related to processes and

products/services [21,22]. Industry 4.0 is decentralized intelligence to facilitate the creation of independent process management through the interaction of the real and virtual worlds. This means that industrial machines no longer just deal with products, but products interact with these machines to tell them exactly what to do [23].

The increase in international competition, the growing volatility of the market, the great demand for diversified services stands out as the main challenges for organizations. Ports are facing a myriad of new complex challenges to meet the high complexity in the production environment while focusing on customer benefit. [24]

The combination of Lean Production and Industry 4.0, known as Lean 4.0, are interconnected and complex elements to implement. It is essential to develop a reference implementation strategy for the port system. Faced with numerous challenges for the port sector and considering that exports and imports pass through ports, it is essential to ensure the efficiency of this sector, which is fundamental for trade and development [25].

On the other hand, to extend sustainability throughout the supply chain, companies often choose to implement different management practices. In the literature, the practices used to manage circularity, efficiency and optimization of resources are called Circular Economy (CE) [26]. EC proposes replacing wasteful and inefficient linear and open production cycles with a closed cycle where waste is minimized or transformed into inputs and value is created in the process, enabling the balance between economic growth and a sustainable environment [27,28].

In an EC model, waste becomes resources to be recovered and valued through recycling and reuse, the value of the resources we extract and produce must be kept in circulation through intentional and integrated production chains [29]. Then, a sustainable approach consists of minimizing negative environmental impacts, reducing the ecological footprint, neutralizing emissions and increasing resource efficiency, that is, continuing to do things in the same way, only with less intensity, but not changing direction, just ensure that future generations are not impacted [30,31].

The EC has gained significant attention at the policy level since the publication of the Action Plan for the EC in 2015. In 2019, the European Commission launched the Green Deal (GD), which is a European green deal with a set of strategic policies articulated by the commission European Union in order to contain the threat of global warming. The circular economy represents an essential component for the future sustainability of European society. In addition, the GD recognizes ports as extremely important entities for achieving sustainability goals [5].

In early 2020, the European Sea Ports Organization (ESPO), representing port authorities in member states of the European Union. A position paper on a GD and circular economy was presented, mirroring seaports as strategic partners in the implementation of GD objectives. Thus, seaports are identified as excellent entities for EC practice and implementation.

This is due to the fact that ports are interconnected with industry and urban areas, constantly exchanging flows of materials and resources, including waste, with the environment of their neighborhood and the interior, so they are essential entities to develop the EC, and has focused on this transition [32].

However, there is limited research on ports and their acceleration to a CE, especially from a practical and implementation point of view [33-35]. Current EC activities in ports are low. Still, substantial improvements are anticipated when ports overcome implementation hurdles, causing the current implementation inhibition in adopting a CE [36]

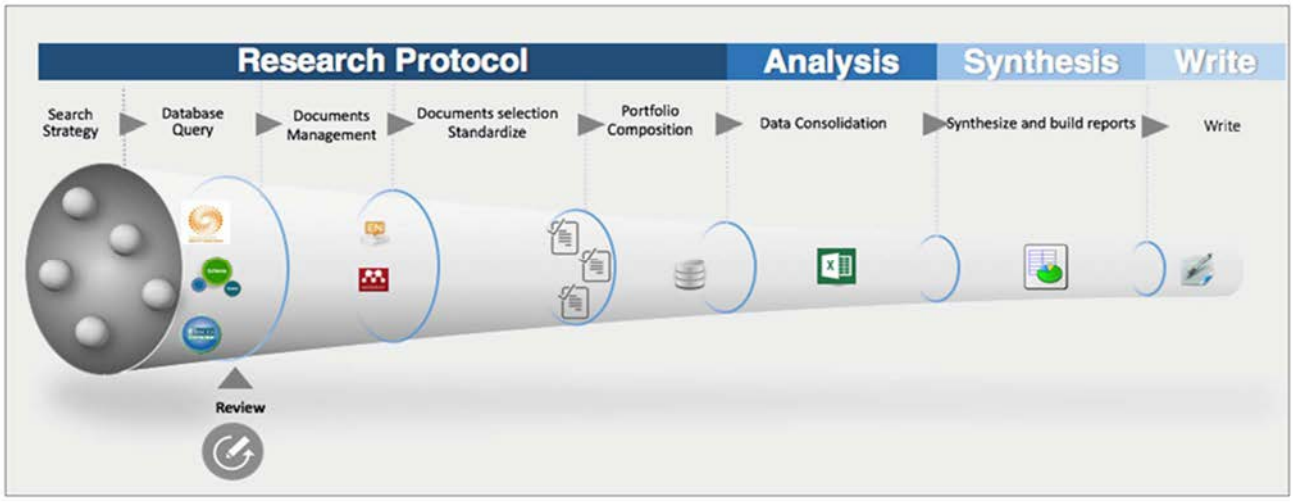
To eliminate waste and ensure an appropriate destination for waste, in 1996 the term Lean and Green (L & G) appears. It addresses the need for environmentally conscious manufacturing, integrating process improvements with reduced environmental impact. Early publications on L&G focused on how to make a link between Lean principles, environmental principles and practices, with emphasis primarily on manufacturing and supply chain management. L&G emerged as a combination of environmental and sustainability concepts. It refers to the synergy between Lean and environmental preservation. More specifically, it focuses on how Lean practices can contribute to reducing environmental impact while keeping profits primarily in operation as well as service and product design. The topic has generated more and more research of interest since 2013 [37]. The different industries in the transport and logistics sector are often targeted for their greenhouse gas (GHG) emissions and their ability to pollute on an intercontinental level. Intercontinental supply chains are strongly centered on seaports, which, due to their interaction with ships that use fossil fuels, generate emissions [38].

3 Research methodology

The present study aims to recognize the links of Lean 4.0 in the port circular economy as an alternative for the development of port management. In this sense, the present work has a qualitative approach, where it is not necessary to use statistical techniques, as this research is descriptive in nature, aiming at identifying, pointing out and analyzing the factors, characteristics, or variables that relate to the process [39].

In order to answer the problems highlighted in the research, firstly, a SLR was conducted based on the SSF method, as a way to recognize in the literature the current theoretical context of Lean and circular economy in the port context [40]. The Figure 1 exposes the steps of SLR conducted.

Figure 1 - SSF method [40]



Following the method SSF, the Scopus, Emerald, Ebsco and Web of Science databases were consulted. The query was carried out on October 17, 2022. For the calibration of the search string, a set of keywords were evaluated, such as Lean, industry 4.0, among others related to the scope of the search, but there was no return on the queries. searches in the consulted databases. Thus, the search string adopted was ("circular economy" AND Lean AND port*). Boolean operators such as “AND”, “OR” and “NOT” were combined in the string calibration step. Table 1 presents the results from the searches conducted in the databases, according to the SSF method [40].

Table 1 Number of documents consulted by database

Source Database	Number of documents
Scopus	61
Web of Science	52
Emerald	44
Ebsco	23
Total Selected Articles	180
Duplicated	(-51)
Total Evaluated Articles	129

As shown in Table 1**,** a total of 180 papers were found in the consulted databases, however, 51 papers were duplicated, which resulted in a total of 151 papers for analysis by the authors. For the analysis of the 151 works, the following research questions were used as criteria for inclusion or for the analysis of the 151 papers, the following research questions were used as criteria for inclusion or exclusion from the resulting portfolio: Does the paper have any managerial implications linked to Lean 4.0 for the development of the circular economy in ports? Does the paper present any insight linked to the development of ports that implies the circular economy? Does the paper have any relationship with the adoption of industry 4.0 for the development of the circular economy in ports?

Then, the title, abstract and keywords of the papers were read, as a first filter. For the resulting papers, the reading of the introduction and conclusion of the papers was carried out. Finally, the complete reading of the resulting papers. Both listed phases were based on the SSF method. A total of 16 papers made up the final portfolio.

Subsequently, the content analysis was conducted. Thus, in the first stage, a pre-analysis was carried out, a bibliographical survey of studies, articles and documents related to the difficulties faced by the port system was carried out, which provided the basis for the study [41].

After that, the interpretation obtained from the previous steps was outlined. In this way, the main limitations to adopting the circular economy in the port system were highlighted, in addition to listing how Lean 4.0 can effectively contribute to solving these challenges for ports. With that, the content analysis was developed with the composition of information that allow the understanding of the researcher in relation to the materials coming from the literature in an orchestrated way [42].

4 Result and discussion

Based on the application of the filters proposed by the SSF method, a total of 16 papers resulted. The jobs are listed in Table 2.

Table 2 Portfolio of works arising from the Bibliographic Review

Code	Title	Author (Year)	Source
A1	A Conceptual Model for Measuring a Circular Economy of Seaports: A Case Study on Antwerp and Koper Ports	Rebeka et al., (2022)	Sustainability
A2	System-based barriers for seaports in contributing to Sustainable Development Goals	Hansini et al., (2022)	Maritime Business Review
A3	Assessing the Possibilities of Integrating Ports into the Circular Economy	Alen et al., (2022)	Tehnicki Vjesnik
A4	An overview of operations and processes for circular management of dredged sediments	Crocetti et al., (2022)	Waste Management
A5	Nexus of Circular Economy and Sustainable Business Performance in the Era of Digitalization: A Comprehensive Review and Network Based Analysis	Rohit et al., (2022)	International Journal of Productivity and Performance Management
A6	Digital Technologies for Sustainable Waste Management On-Board Ships: An Analysis of Best Practices From the Cruise Industry	Assunta et al., (2022)	IEEE Transactions on Engineering Management
A7	A Virtuous Circle? Increasing Local Benefits from Ports by Adopting Circular Economy Principles	Toby et al., (2021)	Sustainability
A8	Port City Sustainability: A Review of Its Research Trends	Ying et al., (2020)	Sustainability
A9	The Role of Seaports in Green Supply Chain Management: Initiatives, Attitudes, and Perspectives in Rotterdam, Antwerp, North Sea Port, and Zeebrugge	Theo et al., (2020)	Sustainability
A10	Seaports as Nodal Points of Circular Supply Chains: Opportunities and Challenges for Secondary Ports	Marta et al., (2020)	Sustainability
A11	Patterns of Circular Transition: What Is the Circular Economy Maturity of Belgian Ports	Elvira et al., (2020)	Sustainability (Switzerland)
A12	Port Strategy for Sustainable Development: Circularization and Value Creation—Introduction to a Special Issue	Elvira et al., (2020)	Sustainability
A13	Circular economy: benefits, impacts and overlapping	Sehnem, et al., (2019)	Supply Chain Management: An International Journal
A14	Circular economy approach to facilitate the transition of the port cities into self-sustainable energy ports—a case study in Copenhagen-Malmö Port (CMP)	Reza et al., (2019)	WMU Journal of Maritime Affairs
A15	Securing a port's future through Circular Economy: Experiences from the Port of Gävle in contributing to sustainability	Carpenter, et al., (2018)	Marine Pollution Bulletin
A16	Deep decarbonisation pathways for the industrial cluster of the Port of Rotterdam	Sascha et al., (2018)	ECEEE Industrial Summer Study Proceedings

After analyzing the articles, we highlighted the most relevant methodologies and studies regarding the opportunities and challenges to be addressed by Lean 4.0 in the circular port economy as an alternative for the development of port management. Table 3 was built after a complete analysis of 16 articles, and then it was separated into the most relevant topics, separated into groups according to frequency.

Table 3 Content analysis

Record Unit	Context Unit	Freq
Efficiency gains	A14- Some EC ports have moved towards less dependence on fossil fuels for renewable sources, systematic improvement of energy efficiency and optimization of waste management	8
	A11- Industries use port facilities that operate beyond port boundaries.	
	A10- Circular supply chains generate a higher demand for transport compared to linear supply chains	
	A12- EC transition from ports may imply shorter, more regional and local flows of goods when favorable transport modes are used	
	A15- EC can help ports respond to challenges and ensure their competitiveness in the face of limited resources, while promoting innovation and reducing environmental impacts port	

	transition can imply shorter, regional and locations when favorable modes of transport are used	
	A15- Research on EC in ports is quite limited, although there are several practical examples in European ports	
	A15- EC in ports can minimize the use of inputs, eliminate waste and reduce pollution, such as maximizing the value created at each stage, improving the management of bio-based resource flows and recovery of non-renewable resource flows in circuit closed efficiency	
	A15- The EC in ports establishes beneficial relationships between companies to promote a circular chain	
Sustainability	A16- The production of base chemicals in the port can shift from using mineral oil products as a feedstock to natural gas liquids, or it can be radically transformed to rely on plastic waste as a feedstock in a cycle approach. closed carbon.	7
	A16- Sustainably produced biomass is a scarce resource that is likely to be needed as a feedstock for low-carbon fuel	
	A8- Ecology is directly related to ecosystem services and sustainable development	
	A8- The development of clean energy technologies contributes to the reduction of pollution in ports and port cities	
	A4- Acid wash to remove heavy metals evidenced in container	
	A15- The port lifecycle in EC literature presents a case study demonstrating how both can be combined to help secure a sustainable future for one of Sweden's largest containers (industrial) ports	
	A15- EC in ports is a synergistic approach that combines economic, logistical and industrial activities with the cultural heritage of the port and the creativity of its wider community, resulting in a dynamic, complex process and a sustainable system.	
Operational Processes	A1- Transition from linear to circular economy using the 9R method that allows a systematic distribution of ten circular economy strategies. These are recovery, recycling, reuse, remanufacturing, refurbishment, repair, reuse, reduce, rethink, and refuse strategies.	5
	A3- “Cradle to Cradle” with the systems thinking approach that aims to extend the usage time for all materials	
	A4- BioGenesisSM sediment washing technology that uses physical and chemical operations to wash and decontaminate pollutants	
	A5- Digitization of processes and documents as one of the CE facilitators	
	A5- The 3R principle, reuse, reduce and recycle resources to reduce environmental impacts	
Operations management	A2- The importance of port management as a success or failure of sustainability	4
	A6- Adoption of digital technologies for waste management processes improved sustainability goals in ports	
	A9- The Sincro Port Platform modality, which aims to implement different means of transport for a logistics service provider in a flexible and sustainable way, as well as digital for waste management processes, has improved sustainability goals in ports	
	A6- Technologies reduce GHG emissions, through synthesis gas generators installed on modern ships and the transformation of waste into exploitable fuel	
Integration of actors	A3- The reverse logistics of materials from the closed cycle effectively contributes to the competitive potential	4
	A7- Cooperation between ports and cities can be drivers of progress in the circular economy in the port system	
	A9- The greening of supply chains building a potential for competitive advantage	
	A12- Collaboration between ports and stakeholder co-creation must be organized, this effectively impacts the transition to the circular economy	
Cultural change	A11- The evolutionary process in ports consists of successive levels of maturity and provides the prerequisites for improvements that lead to the next stage. These levels drive growth based on continuous improvement and incremental changes rather than radical transformations.	3
	A3- Industrial Ecology aims to help companies to use their main resources	
	A7- Land use is one of the biggest obstacles to port industrial development	

Investment in the sector	A10- Chains with dangerous loads, require appropriate administrative licenses, or when the production plant in the port uses pollution-intensive technology, obstacles can be overcome by ports through investment in alternative technologies	2
	A14- There are port challenges such as insufficient budget, allocation of sources to transition from the linear structure of the ports to circular models and integration of port development plans in the city's municipal plans.	
Labor Qualification	A14-Ports suffer from a lack of specialists, professional role and validated business for new circular models.	2
	A14- There is no clear balance of responsibilities and gains between the urban areas of the city and the port areas	

After Aspects related to the findings presented in Table 3 for each of the groups are discussed below, in order to assess the managerial implications and/or correlation of Lean 4.0 for the adoption of the circular economy in the port sector.

A) Efficiency gains

From the adoption of Lean 4.0 Lean 4.0 in the port circular economy as an alternative for the development of port management, advantages of efficiency gains can be observed, since the EC can help ports to respond to challenges and ensure their competitiveness in a world with limited resources, so that inefficiencies and waste in the port sector are combated, as well as the flow can be improved in ports [10,12].

In this sense, innovation can be a strategy for mitigating environmental impacts, from the internal perspective of the port and the neighboring community of port regions [15]. In this sense, the reduction of pollution through the use of alternative fuels can be considered as an example, which can impact on the reduction of production costs and environmental protection, via the reduction of emissions from ports [15].

At the same time that it promotes innovation and reduces environmental impacts, considering that ports are relevant indicators for the world economy, due to their role in global production and distribution systems. For this reason, they are under increasing pressure to become increasingly environmentally conscious [31,61].

EC in ports focuses on: minimizing the use of inputs and the elimination of waste and pollution, maximizing the value created at each stage, management of bio-based resource flows and recovery of non-renewable resource flows in a closed loop. In this way, the closed-loop model, based on the circular economy, becomes viable, seeking to add value to the large amount of waste generated in the port sector. Some EU ports have moved towards less dependence on fossil fuels for renewable sources, systematically improving energy efficiency and optimizing waste management, in response to resource performance. With this, the aim is to replace the linear model that the port system currently adopts “take-do-discard” with sustainable structures [43].

Circular supply chains generate a higher demand for transport compared to linear supply chains, which has an impact on the efficiency gain of circular chains [32]. Circular chains are strategies and have the ultimate goal of interactively supporting sustainability [44]. Therefore, via Lean 4.0 applied to the port sector, it can positively impact the reduction of environmental problems, increase its operational efficiency and higher quality of customer services, as well as economic benefits and environmental preservation for the port sector and society [33].

B) Sustainability

Sustainability has become one of the main issues when related to development in society and in the industrial sector. In port cities, the sustainability relationship related to the operating limits between ports and ships is one of the factors promoting a with Lean 4.0 approaches, and many ports operate beyond their limit. Lean 4.0 brings sustainable gains in the sector port, the sustainability category brings techniques to reduce gas emissions through systems for transforming waste into fuel, which acquire the possibilities of being explored by ports [45].

The production of base chemicals in ports can shift from using mineral oil products as a feedstock to natural gas liquids, or it can be radically modified to give rise to plastic waste as a feedstock in a cycle approach. closed carbon. Sustainably produced biomass, on the other hand, is a scarce resource that is likely to be needed as a feedstock for low-carbon fuel [46].

In this way, the development of clean energy technologies seeks to generate a broad perspective for the reduction of pollution in ports and cities [47]. For this reason, the EC concept is an important factor for ports to respond to challenges and ensure their competitiveness in the face of limited resources, while promoting innovation and reducing environmental impacts [31]. Another strategy for removing pollutants is acid washing to remove heavy metals and the BioGenesisSM sediment washing technology to wash and decontaminate sediments. This technology has already been adopted in ports of Venice, New York and New Jersey, its removal varies from 60 to 80%, depending on the sedimentary matrix [48]. In this way, we can highlight as an important factor for the impact of the environment a “green” management for companies that get involved in the supply chain, allowing to obtain a competitive advantage and, even so, to contribute to a sustainable environment [50].

In this sense, studies demonstrate the advancement of technology in equipment at container terminals as the main factor in creating value in terms of port sustainability, as the use of advanced technologies can reduce operating costs and improve efficiency, while at the same time minimizes the environmental impact.

For example, equipment such as cranes, forklifts and conveyors are responsible for handling cargo within ports and with the advancement of technology they have become more efficient and less polluting. In addition, the technology can also be used to improve safety in the workplace by reducing the risk of accidents, with sensors and cameras to monitor the movement of equipment and loads, and the implementation of warning systems to avoid collisions and other risk situations. It is, therefore, a crucial sustainability factor in ports, allowing them to become more efficient, safe and environmentally responsible [57].

C) Methodological tools

In the topic of methodological tools, we highlight the use of technologies to assist the port system in the transition to EC that can be implemented through the Lean 4.0 methodology. Smart digitization stands out as one of the transitions to EC, creating possibilities for new flows and greater data control, reducing the number of leaves that are usually used in these processes, and consequently reducing carbon emissions into the atmosphere [49,62].

The 3R principle is an important approach to sustainability in the port sector, as it seeks to minimize waste and reduce environmental damage in ports, promoting the most efficient use of resources and waste reduction. Reuse involves the practice of reusing materials or products before discarding them, this can include reusing transport packaging such as wooden or plastic crates rather than simply discarding them after use. The reduction, on the other hand, brings a decrease in the consumption of resources and materials, involving the reduction in the use of energy, water and raw materials in the port operation.

While, recycling, seeks to transform waste into new products or materials, reducing the amount of waste that ends up in landfills or in the environment, with programs for selective collection and recycling of solid waste, such as cardboard, plastic and metal. In addition to the 3R, other sustainable practices in the port sector include the proper management of hazardous waste, the conservation of local biodiversity, the use of renewable energy sources and the promotion of environmental education among port workers and the local community [49].

The importance of the transition from the linear to the circular economy is highlighted, through the 9R method, which uses recovery, recycling, reuse, remanufacturing, reform, repair, reuse, reduction, rethink and refuse strategies, enabling a systemic structuring of ten circular strategies of the economy through the recognition of weaknesses, strengths, opportunities and possibilities for improvement. This method provides us with a detailed view of the circular processes of seaports from the indicators and makes it possible to use the method as a facilitator for the implementation of this new model in the port system, enabling the construction of a human behavior in commitment to environment [5]. The Cradle-to-Cradle approach of Lean, which consists of creating products and industrial processes inspired by natural methods, increasing the useful life of materials used in ports, contributing to environmental preservation, reducing pollution and soil contamination, in addition to energy savings [49].

D) Operations management

The Operations Management category shows how the perception of port management of a port can influence the success or decline in development and recognize the implications of Lean 4.0 for the development of the port circular economy. In this case, an innovative port management is necessary in terms of managing the system and implementing a new philosophy in the sector [7,52].

Ports and maritime shipping networks are essential for transporting goods and materials in the global supply chain, but they can also be significant sources of energy consumption and pollution. Ships and port operations consume large amounts of fossil fuels, emitting greenhouse gases and other pollutants that affect air and water quality. To mitigate emissions from ships in ports, it is essential that port managers adopt sustainable practices and seek innovative solutions to reduce the environmental impact and promote sustainability in their operations [51].

Investment and the search for digital technologies are presented as a contribution to the development of a “green” culture in ports. The adoption of these technologies aims to bring about improvements in indicators in the fulfillment of sustainability goals when applied, for example, in waste management processes. In this way, it is possible for ships to map the stages of waste disposal or recycling and establish short-term events during the voyage, not only sharing data regarding the use of digital technologies in individual processes, but also developing best practices in the port system [45].

At the same time, the flexible and sustainable deployment of diverse transport modes in a logistics service provider framework. This allows the customer (shipper or dispatcher) to obtain an integrated transport solution called Synchro modality. Thus, it is defined as the flexible and sustainable deployment of different modes of transport in a network under the direction of a logistics service provider [48].

E) Integration of actors

From the adoption of Lean 4.0 to promoting a CE in the port sector, one can observe the advantages of cultural change in the face of the challenges of the sector. Despite the existing conceptual diversity, it is possible to note that the idea of innovation is related to changes and new factors that disrupt the existing balance [53].

In view of this, it is essential that this change be promoted in view of the transformation of procedures and the need for adaptability of employees, resulting in the recognition of the benefits achieved with the development of the port circular economy. The evolutionary process in ports at successive levels of maturity provides the prerequisites for improvements leading to the next stage.

Integration between actors from a Lean 4.0 perspective can be characterized, for example, with the collaboration of ports with other actors in the business environment, which go beyond the value stream (value chain), such as universities and centers of research, which require knowledge and information to help build the circular economy in the port system and can bring many benefits to the implementation of this new approach such as knowledge sharing, since universities are institutions that constantly produce knowledge and innovation, and can bring new perspectives and solutions for the challenges faced by the port sector and the awareness and engagement of the population with the active participation of the whole society, including companies, consumers and governments, resulting in the development of research projects that seek innovative solutions for specific challenges faced by the port sector [36,63,65].

Industrial ecology and the contribution to the use of key resources by companies account for a product throughout its life cycle, such as tracking the flows of materials, energy and water [52]. At the same time, the use of land as the main obstacle in port industrial development, both approaches cause a change of culture due to greater exploitation of existing resources [36].

F) Cultural change

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These changes involve the transformation of procedures, the need for adaptation of employees and the recognition of the benefits achieved with the development of the circular port economy. Employees in the port sector play a key role in adopting more sustainable practices and promoting the circular economy, and it is important that they are engaged and committed to this change in the routine of professional activities [56] and that they receive adequate training and support to become adapt to new ways of working and thinking, recognizing the benefits achieved with the implementation of the circular port economy, such as cost reduction, improved operational efficiency, promotion of innovation and strengthening of the institutional image [6].

In this sense, the promotion of cultural change in the port sector requires leadership and commitment on the part of companies and institutions in the sector, in addition to a long-term strategic vision. Only then will it be possible to promote the necessary transformation for the implementation of the circular economy and for the construction of a more sustainable and efficient port sector [36,53,56].

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In addition, citizens play an important role in driving the transition to a circular economy and are increasingly central to the implementation of other strategies in different sectors, influencing the demand for circular and sustainable goods and services, having a positive impact on the transition to a sustainable port [58].

G) Investment in the sector

From research on the adoption of Lean 4.0 to promote a circular economy in the port sector, one can observe the need for and importance of investments in the sector. These investments can generate positive results, due to the intense connection with transport modes, technological development, job growth, as well as improvements in the infrastructure of the cities in which they are located and their surroundings [56]. Investment in alternative technologies helping ports to overcome obstacles, such as dangerous cargo chains, appropriate administrative licenses, when the production plant in the port uses pollution-intensive technology [35].

The port system faces challenges such as insufficient budget, allocation of sources to transition from the linear structure of the ports to circular models, integration of port development plans in the city's municipal plans, causing interference and delay in the development of ports.

In this way, some measures and investments can be considered important for the implementation of these practices, such as updating and modernizing the port infrastructure, including the implementation of state-of-the-art technologies and equipment that allow greater operational efficiency and lower energy consumption, qualification and training of employees to adopt Lean 4.0 and the circular economy, in addition to creating incentive programs so that employees are more engaged and committed to sustainability. In addition, the implementation of environmental management systems

and certification by regulatory bodies can be important to ensure that the adopted practices are effective and internationally recognized [54].

Finally, we can highlight the need for investments in research and development of new technologies and solutions for the implementation of the CE in the port sector. This can be done in partnership with universities and research institutions, aiming at innovation and continuous improvement of adopted practices [43,62].

H) Labor qualification

With the aim of recognizing the main implications of Lean 4.0 for the development of the circular port economy, the contribution of qualified professionals during this transition is important. The results of an organization are related to the capacity of its professionals, however, the number of companies that prioritize professionals of excellence is still low [55].

The shipping industry is one of the most globalized of all industries, characterized by complex modular supply chains, including a large outsourced workforce of temporary workers from developing countries and countries in transition around the world. Despite long-standing efforts by international bodies to regulate the education and training of seafarers, differences in practices and standards persist [43,60]. In this sense, Lean aims at the continuous development of people, through development through the management of the professionals' routine, thus, the organizational culture of employees in the port sector aimed at continuous improvement, from the perspective of Lean, are based in training and development of people based on the scientific method [56].

Due to the lack of qualified professionals, there is no clear balance of responsibilities in the port sector, in addition to the lack of experts and validated businesses, which makes it difficult to develop circular models in ports [43]. The qualification of the workforce is an important factor for developing professionals, enabling them to understand their responsibilities and obtain results such as qualified labor and operational efficiency for the development of ports in the EC context [10]. In addition, Lean 4.0 allows developing new skills and abilities of employees through learning routines [40], so that obstacles linked to lack of knowledge, methods and techniques for adopting EC in the port sector can be developed from the Lean perspective. The Toyota Kata concept allows the development of a culture of continuous training of employees based on Lean and the scientific method to deal with the continuous improvement of the port sector and change in the culture of the actors in the port sector [56].

5 Conclusion

Based on the findings, it was possible to recognize the contributions and support coming from Lean 4.0 in ports and terminals. Among the impacts include gains in efficiency, sustainability, operational processes, management of operations, integration of actors, cultural change, investments in the sector and qualification of the workforce. In addition, Lean 4.0 allows for guidelines for actions aimed at reducing errors and operating time in production, increasing production and reducing costs and using resources, reducing operations and increasing supervision. In addition, the management tools arising from Lean in line with the technologies of industry 4.0 make it possible to streamline support in decision-making in an agile way. Through the listed actions, port processes and operations can be improved from a sustainable perspective. Since Lean 4.0 is an enabling approach for implementing improvements in the sector.

Thus, the tools from Lean 4.0 can help deal with the root cause of the port sector's obstacles in the transition to EC and avoid future problems, driving an improvement in port management within the national and international competition environment. In this way, it is possible to apply the Lean 4.0 concept in the port circular economy and obtain efficiency gains, develop a sustainable port, use methodological tools for the development of port management, promote cultural change and the qualification of the workforce.

Lean 4.0 practices tend to be impactful, as the foundations of Industry 4.0 allow a better understanding of customer demands and accelerate the processes of sharing information in real time. With this, it improves efficiency and port operations in order not to exceed service limits and promote a circular and sustainable port.

The achievement of results in ports will depend on technology and operations strategies, to be able to operate in conjunction with processes, trained and qualified professionals is essential to promote a change in culture and procedures, since the findings indicated that Lean 4.0 presents itself as a simplifier for the implementation of EC and innovative technologies for the development of ports, since it enables the alignment of a new management that identifies waste, develops a culture based on the proposed model and increases the competitiveness of the sector.

Based on the findings of the study, we show that Lean 4.0 allows reducing waste in port processes and operations, as well as presenting lean and technological strategies for the development of a modern and sustainable port. So that the port sector transitions from the linear economy to the circular economy, guided by the Lean 4.0 concept.

This work is limited to theoretical findings arising from systematic searches in the literature. Thus, future studies can be directed to identify in practice the challenges and strategies to adopt EC in ports in the perspective of Lean 4.0.

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Exploring the drivers and barriers to digital transformation adoption for sustainable supply chains: a comprehensive overview
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Exploring the drivers and barriers to digital transformation adoption for sustainable supply chains: a comprehensive overview

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Keywords: digital transformation, sustainable supply chains, barriers, drivers, literature review.
Abstract: In today's manufacturing industry, digital transformation has become a focal point for academia and practitioners due to its potential to drive supply chain management and sustainability outcomes. This transformation provides numerous opportunities to improve strategic, tactical, and operational capabilities to meet sustainability goals. However, the high level of uncertainty associated with digital transformation programs has created doubts among many manufacturing companies about the successful adoption of digital transformation in their supply chain processes. While previous studies have examined digital transformation technologies and their implementations in supply chains, little attention has been given to the drivers and barriers associated with adopting digital technologies for sustainable supply chains, especially in the context of manufacturing. Therefore, this study aims to fill this gap by providing a comprehensive overview of digital transformation adoption in manufacturing supply chains and identifying the critical drivers and barriers to successful digital transformation implementation. A total of six barriers and eleven drivers have been selected from the literature. Finally, this study provides insights for decision-makers to overcome the main barriers that hinder the successful implementation of digital technologies in supply chain functions, which can lead to a higher ethical supply chain level from a sustainability and operational efficiency perspective.

1 Introduction

Over the past few years, the term "digital transformation" (DT) has gained significant importance in the business world [1]. This is due to the impact of digital technologies on manufacturing processes, which has led to a change in the way businesses operate. This change is often referred to as the second machine age. Due to the competitive and volatile nature of the trading environment, organizations must develop capabilities to handle technological and operational mutations [2]. Thus, DT has become a buzzword concept. For example, in Germany, the transformation of manufacturing companies into digital entities is called "Industry 4.0" [3], whereas in the United States, the term "industrial internet" is commonly used [4]. However, DT is broadly characterized as leveraging digital technologies to devise novel business models and opportunities that align with the rapidly changing business landscape, which puts intense pressure on supply chain managers [5]. As a result, many organizations have adopted DT to improve systems integrations [6]. The significant transformation in supply chain management (SCM) is due to the emergence of disruptive technologies under digital transformation, such as the internet of things (IoT), cyber-physical systems (CPS), big data analytics (BDA), machine learning (ML), cloud computing (CC), radio frequency identification (RFID), and business-to-business (B2B) networks. These technologies have the potential to revolutionize the way SC processes are executed by making them more efficient, transparent, and secure [3,7]. In addition, they help manufacturing companies enhance flexibility, transparency, and productivity, generate innovation and optimize SC operations. Therefore, integrating digital transformation technologies into business models and SC operations leads to more efficient and sustainable operations [2]. DT involves the entire business and needs to be integrated into corporate strategy. It allows firms to achieve more satisfactory customer service, enhanced relationships with suppliers, creating real-time visibility on their internal and external operations, and thus, a more potent competitive edge [8,9]. Reaching well-balanced sustainable supply chain performance levels depends on tracking current technological trends and being aware of digital transformation while focusing on operational excellence. In this context, DT represents a strategic decision that can result in improved supply chain performance and competitive advantage [10,11].

Despite the potential advantages and benefits of DT in SC operations, its adoption is subject to high levels of uncertainty, leading many manufacturing companies to doubt its adoption. This uncertainty arises from the various operational, environmental, social, and financial factors that affect the long-term performance of companies [12,13]. However, DT adoption in sustainable supply

chains (SSCs) is not free from barriers. Few scientific studies have been conducted on the barriers to DT adoption. Some have developed a conceptual framework to address these barriers in the manufacturing context [12], while others have focused on analyzing the barriers to DT adoption in the supply chain context [9], High-Technology Manufacturing [14], and logistics service providers [15]. Some research has even looked into barriers specific to micro, small, and medium-sized enterprises (MSMEs) [16]. However, there are only a few studies on the drivers and advantages of DT adoption in the supply chain context [15,17,18].

However, current research has not tackled the taxonomy of DT drivers and barriers in SSCs from a manufacturing context. To fill this gap, the authors have conducted a comprehensive overview of DT adoption drivers and barriers in the sustainable supply chain context. The novelty of the proposed paper includes the selection of the DT adoption drivers and barriers in SSCs from a manufacturing perspective based on current literature. Therefore, the main objective of the proposed study was translated into the following research questions:

- **RQ1.** What barriers hinder DT adoption in SSCs from the manufacturing context?
- **RQ2.** What are the drivers of DT adoption in SSCs from the manufacturing context?
- **RQ3.** What insights can be provided to practitioners and policy-makers to overcome the identified DT adoption barriers?

The paper is structured as follows: Section 2 describes the methodology used to conduct the study. Section 3 provides a comprehensive review of the relevant literature. In Section 4, the study focuses on identifying the drivers and barriers to DT adoption in SSCs. The main findings and related discussion are presented in Section 5. Section 6 discusses the study's implications. Finally, the conclusions and recommendations for future research are outlined in Section 7.

2 Research methodology

The first objective of this study is to conduct a literature review focused on DT technologies and their adoption in SSCs, with the aim of identifying the key drivers and barriers associated with DT adoption in SSCs. To achieve this, the authors have used online databases such as SCOPUS and ISI WEB OF KNOWLEDGE to select relevant peer-reviewed journal papers and book chapters. These databases are widely recognized as two of the most comprehensive and reputable academic research tools globally [11]. In addition, a total of eleven drivers and six barriers to DT adoption in SSCs have been selected through an extensive literature review.

Figure 1 provides an overview of the step-by-step research methodology followed in this study.

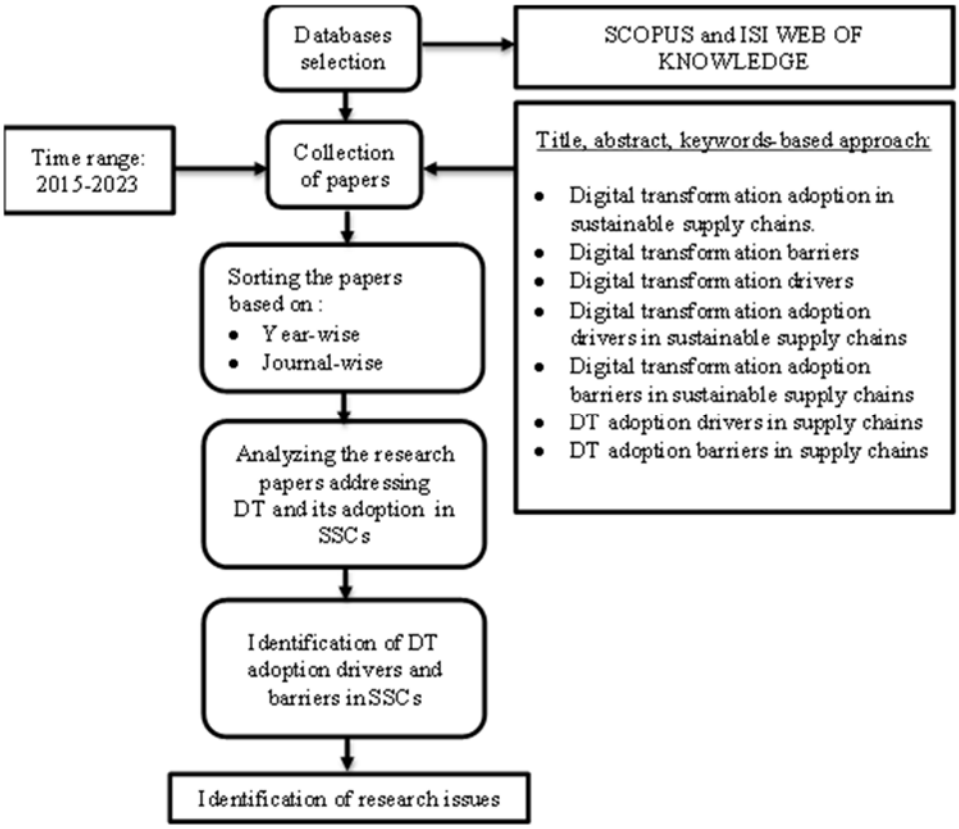

Figure 1 Step-by-step research methodology

3 Literature review

3.1 Digital transformation

DT has become widely recognized as a driving force for academicians across various disciplines, as well as practitioners and decision-makers [15]. DT involves digital platforms, high-level asset management, and inter-organizational and intra-organizational interactions induced by digital technologies [2,19]. Over the 21st century, the digital policy has evolved from a decentralized hierarchical functional structure to a globally connected IT-enabled network structure [20]. DT enables new business workflows and extends the trading environment by utilizing digital technologies [21]. At a high level, DT leverages digitally integrated technologies to develop more intelligent manufacturing processes. Innovative technologies under digital transformation, such as IoT, CPS, BDA, ML, CC, and RFID, lead to smarter production processes as they are the prerequisites for a smarter cross-linkage of systems [22,23]. According to Nayal et al. [13], DT is the process by which organizations transform their business models and eco-system by engaging digital capabilities. Also, digital technologies provide numerous socio-managerial and strategic opportunities for organizations. They generate opportunities to create more flexible, responsive, and integrated business models by networking with a broad range of partners, including customers and suppliers [24]. Due to these disruptive technologies, companies could generate additional customers, revenues, and business value [25]. Thus, DT features a new way of using and connecting digital technologies, blurring corporate boundaries [26] and allowing new market behaviours and transactions [27]. Despite being risky, DT drives long-term organizational performance by reshaping the overall financial value-creation process [28], particularly internal processes and customer and supplier relationships [29,30]. Therefore, decision-making has shifted from the asset level to the fleet one [31].

Despite the numerous benefits of DT, the adoption of DT is challenging for incumbent organizations. As they seek to break new ground in their digital business model, they frequently face trade-offs between traditional and new working methods [32,33]. In short, Digital transformation leads to three fundamental changes within companies, namely digitally-enabled and interconnected operations, digitally-enabled communication, and new value creation patterns through digital innovation or acquired digital data. These changes are evident across all industries worldwide. Organizations could initiate minor changes, such as disconnected digitization efforts, to progressively shift their traditional business model into a digital one. However, DT can require a significant deviation from the status quo and make existing business models obsolete [34,35]. As a result, DT forces companies to reconsider their managerial practices [27,36]. So, manufacturing companies need to develop their digital capabilities to reshape how they create and deliver value to their customers [37].

3.2 Digital transformation for sustainable supply chains

Digital technologies arising under the DT umbrella have created numerous opportunities and positive expectations for reducing the environmental impact of expanding supply chains and conserving resources [2,38]. DT technologies across the SC network help achieve SDGs by creating more visibility into the system concerning emissions [39]. This highlights the need to move from a classical supply chain to a sustainable and digitally enabled one [26,40]. This transformation includes product development, procurement, manufacturing, logistics, suppliers, customers, and services [41]. In addition, DT technologies provide crucial advantages for SCs, such as improving information availability and creating real-time transparency, agility, and flexibility, which leads to improved profitability and efficiency, optimized SCM practices, and reduced cost and delivery times, thus, contributing to sustainable development [2,42].

For example, blockchain technology (BT) is a decentralized technology that guarantees information transparency, traceability, and security. BT differs greatly from other information systems (IS), such as enterprise resource planning systems (ERP), by having four key features in its design: non-localization (decentralization), security, verifiability, and intelligent execution [43]. During the last years, companies adopted ERP systems for their SC processes [44]. However, they lacked an overall view of their SC, as they were unable to track their products' status beyond their SC network [45]. Moreover, ERP, as a centralized system, saves all information in a single central location/server, which makes it easy to be attacked, corrupted, and hacked [46]. BT is a solution for this issue as it improves SC processes and makes the SC system energy efficient, thus increasing customers' trust and further enhancing SC performance [47,48]. Furthermore, BT plays a crucial role in achieving SC sustainability, addressing sustainability challenges through the use of immutable and decentralized data, transparency, and smart contractual relationships to solve growing sustainability concerns [49,50]. Aside from the above, BT could decrease the environmental and social issues related to SC by reducing and controlling the recall and rework [51].

Likewise, IoT meets the requirements of the sustainability pillars [52]. It involves a set of devices interconnected with each other to exchange data that require minimal or no human intervention by using sensor-based technology. IoT technology could contribute to operational efficiency and revenue growth, providing a competitive advantage for companies that can implement it [53]. However, IoT also poses security risks and struggles to manage and control information shared among stakeholders [52,54]. To address this issue, IoT can be

integrated with BT to enable effective stakeholder data exchange and enhance SC profitability [54,55].

Furthermore, big data analytics (BDA) is characterized by the collection, extraction, and storage of massive datasets, commonly known as the "6Vs" (Volume, velocity, variety, value, veracity, and variability) [56]. It associates with analyzing and examining extensive amounts of data with variable types to identify hidden patterns, trends, and correlations using advanced technologies to enhance operational efficiency and further explore new markets and opportunities [57]. BDA has become vital for organizations and society [58]. Indeed, the complexity of supply chains makes monitoring SC functions difficult, especially when following a sustainability agenda, since some SC players might not be transparent [59]. However, BDA helps to analyze data from each SC player at different decision-making levels, which can help in SC planning and visibility decisions [60]. From the sustainability perspective, BDA could minimize delivery time by integrating numerous customers, which can be achieved through real-time information sharing, thus reducing energy consumption [61,62]. Also, BDA allows SC members within each SC function to uncover unsustainable and unethical activities or other negative environmental conduct, as well as it could measure carbon emissions and air pollutants [63,64]. BDA applications are also likely to support SSCs from the social dimension by minimizing SC risks related to the procurement of goods/services [65]. Additionally, BDA can minimize supply chain risks related to procurement and support social sustainability. By comparing past performance with present and predicting future social problems, BDA capabilities align with the Triple Bottom Line and contribute to enhancing sustainability performance [56,60,65].

4 Identification of digital transformation adoption drivers and barriers for sustainable supply chains

As previously stated, despite the strengths and advantages of DT technologies in SC operations and sustainability concerns, research on DT adoption in SSCs has been unexplored in the extant literature review. Manufacturing firms strive to reach the global competitive advantage of products and services while achieving sustainable development goals. This comes by creating more visibility and transparency in SC operations. Therefore, designing digital and sustainable supply chain systems is needed to enhance SC profitability and effectiveness and achieve SDGs. However, DT adoption is not free from barriers. For this paper, barriers are related to factors that hinder and prevent the implementation of DT in the sustainable supply chain context. These factors affect manufacturing companies' efforts to adopt DT technologies from a sustainability perspective. However, the drivers of digital transformation adoption in SCs refer to the factors that motivate organizations to adopt digital technologies and strategies to improve SC operations.

Tables 1 and 2 summarize the literature related to drivers and barriers to digital technologies adoption in supply chains.

Table 1 Summary of studies investigating drivers of DT adoption in different supply chains

References	Analytical methods	Key features
Gupta et al. [7]	Literature review and Best-Worst Method (BWM) based on experts' opinions.	Identification and ranking of digitization enablers for supply chain performance improvement.
Yang et al. [25]	Literature review	Identification of the main drivers behind manufacturing firms' adoption of digital technologies
Queiroz et al. [32]	Conceptual analysis	Exploring the enablers and capabilities of digital supply chains.
Agrawal and Narain [35]	Literature review, expert interviews, and Interpretive Structural Modeling (ISM).	Identification and Analysis of the key enablers for digital transformation implementation in supply chains
Alzarooni et al. [36]	Literature review, Decision-making trial and evaluation laboratory (DEMATEL), and Interpretive Structural Modeling (ISM).	Identification and analysis of the main enablers for digital supply chain transformation in the service industry
Yadav and Singh [48]	Principal Component Analysis (PCA) and Fuzzy-Decision-making trial and evaluation laboratory (DEMATEL).	Identification and analysis of blockchain critical success factors for sustainable supply chains.
Attaran [66]	Literature review	Exploring digital technology enablers and their implications for supply chain management.

Table 2 Summary of studies investigating barriers to DT adoption in different supply chains

References	Analytical methods	Key features
Kumar Dadsena and Pant [6]	Literature review and Fuzzy Analytic Hierarchy Process (FAHP) based on experts' opinions.	Identification and ranking of supply chain digitalization barriers in the light of sustainable development goals.
Agrawal et al. [9]	Literature review, experts' interviews, and Interpretive Structural Modeling (ISM).	Identification and analysis of the major barriers to digital transformation implementation in supply chains.
Jones et al. [12]	Literature review and research agenda.	Description of DT in manufacturing and the main barriers to adopting it before, during, and after the COVID-19 pandemic.
Kouhizadeh et al. [49]	Literature review and Decision-Making Trial and Evaluation Laboratory (DEMATEL) based on experts' opinions.	Analysis of the main barriers to Blockchain technology (BT) adoption in sustainable supply chains.
Chaouni Benabdellah et al. [50]	Literature review, Analytical Hierarchy Process (AHP) method, and Decision-Making Trial and Evaluation Laboratory (DEMATEL) based on experts' opinions.	Identification and ranking of the barriers to Blockchain technology (BT) adoption in viable circular digital supply chains (VCDSCs).
Kusi-Sarpong et al. [57]	Literature review and Best-Worst Method (BWM) based on experts' opinions.	Selection and analysis of the main risks associated with the implementation of big data analytics (BDA) in sustainable supply chains.
Moktadir et al. [61]	Literature review, Delphi technique based on Analytic Hierarchy Process (AHP).	Analyzing the major barriers to the implementation of Big Data Analytics (BDA) in supply chains within the manufacturing industry in Bangladesh.
Selçuk Perçin [67]	Literature review, Delphi method, and Pythagorean fuzzy analytic hierarchy process (PFAHP) based on experts' opinions.	Identification of barriers to big data analytics (BDA) adoption in circular agri-food supply chains in Turkey.
Bag et al. [68]	Literature review and Fuzzy Total Interpretive Structural Modeling (TISM).	Exploring the main barriers and their interactions with BDA in sustainable humanitarian supply chains
Raut et al. [69]	Literature review, DEMATEL, Interpretive Structural Modeling (ISM), and fuzzy MICMAC.	Identification and analysis of BDA implementation challenges in Indian manufacturing supply chains.

Through literature review, both drivers and barriers to DT adoption in SSCs have been identified. The most critical drivers and barriers have been selected considering the manufacturing and sustainability contexts. Indeed, the DT adoption drivers include process improvement, workplace improvement, cleaner production, vertical and horizontal integrations, visibility, information sharing, sustainable technology capabilities, cost savings, waste, and emissions reduction [1,66,70]. However, the DT barriers involve organizational barriers which are related to lack of top management support and strategic orientation and the lack of organizational readiness [9,61,68,69], technological barriers which refers to lack of digital skills and infrastructural facilities, privacy and security concerns, low maturity levels of DT technologies, and scability challenges [61,70], financial barriers which are related to high implementation and running cost, high sustainability cost, and return on investment (ROI) issues [68,69,71], external barriers which reflect the market competition and demand uncertainty, lack of stakeholder involvement in DT adoption, lack of industry commitment to ethical and safe practices, legal and regulatory uncertainties, and velocity of technological development [50,61,70,71], social and environmental barriers which are related to low environmental regulations, wasted resources, lack of qualified human resources, lack of information sharing quality, lack of understanding of the interplay between technology and human beings, lack of collaboration between stakeholders and Lack of SC partners' awareness about social and environmental concerns and digital transformation technologies [9,39,50,68,70]. Figure 2 and 3 summarizes the DT adoption barriers and drivers in SSCs.

Exploring the drivers and barriers to digital transformation adoption for sustainable supply chains: a comprehensive overview

Imadeddine Oubrahim, Naoufal Sefiani

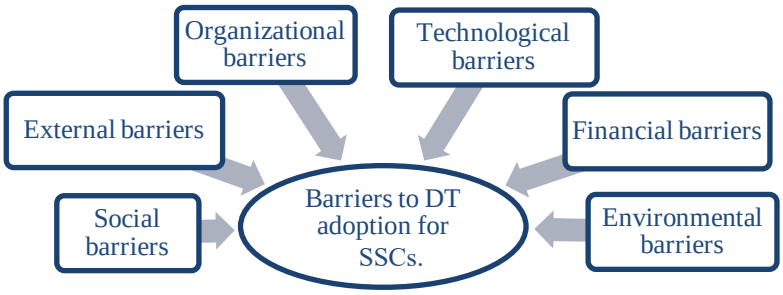

Figure 2 Barriers to DT adoption for sustainable supply chains

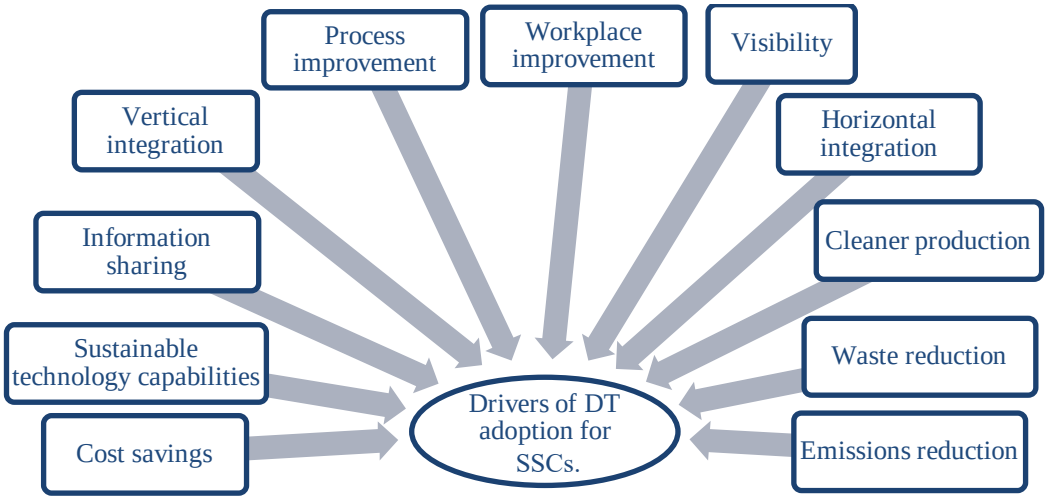

Figure 3 Drivers of DT adoption for sustainable supply chains

5 Findings and discussion

A total of six barriers and eleven drivers have been selected from the literature review. The barriers to DT adoption have been categorized into six dimensions: organizational, technological, financial, external, social, and environmental. Organizational barriers refer to the lack of management commitment, support, and strategic orientation. Indeed, SC managers need to make long-term commitments and support sustainable supply chain management practices using DT technologies. Hence, top management support is required for a sustainable and digitally enabled supply chain [9,70,72]. An organization needs to define various strategic orientations, such as customer and supplier orientations, technological orientation, and smart orientation, to create successful sustainable and digital transformation initiatives. Yet manufacturing companies worldwide need more management support, leadership, and relevant experience to take advantage of it. In addition, it provides a clear vision and strategy for digital transformation programs in companies. In fact, older employees are unfamiliar with the latest technology and their benefits, so without top management commitment, these employees will resist change. Moreover, organizational barriers also address the lack of organizational readiness. So, manufacturing companies need to create a cultural shift to cultivating a data-centric mindset [68,73]. Technological barriers refer to the lack of digital skills and infrastructural facilities. Most of the current technologies are still not able to meet the present infrastructure needs. For example, to run BDA programs, data collection, storage, and processing are challenging due to the lack of infrastructure readiness [70,73]. Also, digital skills include IT knowledge, machine learning, data mining, and optimization [59,66,70]. However, these skills are lacking in the manufacturing context, especially in under-developing countries. Privacy and security concerns can discourage SC managers from implementing DT technologies. Data security and privacy are critical barriers to manufacturing companies that are worried about hacker attacks. This could be possible due to the increasing exchange of information between suppliers and customers. Data security is needed for companies to compete in the global market [61]. Furthermore, low maturity levels of DT technologies and scalability challenges are also affecting DT implementation in supply chain systems. These technologies may lack stability and consistency regarding standards, and the increasing number of partially tested devices may lead to uncertainty [73,74]. Financial barriers refer to high implementation and running costs, high sustainability costs, and ROI issues. Indeed, data collection across the supply chain network and conversion to a digital system are costly for companies. Similarly, sustainability practices adoption impose costs. Furthermore, the ambiguity and lack of clarity on ROI benefits make stakeholders reluctant to

implement DT technologies. The fear of a failed DT implementation leads to a loss of confidence in recovering the investment made. Otherwise, high investment needs to guarantee the readiness of new digital technologies, resources, skilled workforce, and new organizational capabilities. Manufacturing companies need to provide digital technologies training, such as IT systems training to their workforce to achieve a positive return on their digital transformation efforts [41]. External barriers reflect the market competition and demand uncertainty, lack of stakeholder involvement in DT adoption, lack of industry commitment to ethical and safe practices, legal and regulatory uncertainties, and velocity of technological development. In fact, the adoption of sustainable practices and digital technologies into SC operations is time-consuming [67]. This could affect the organization's market competitiveness and ultimately provide competitive risks, including uncertainty regarding the market demand for sustainable products, customer behavior, and future sales [49,75,76]. External pressures and support from external stakeholders to adopt sustainability practices and DT technologies could push manufacturing companies to integrate them into their SC operations and activities. However, the inappropriate government and industry policies and commitment to drive and support sustainable and safe practices act as a roadblock to achieving sustainability and advanced technologies in business processes [43,49]. Finally, social and environmental barriers refer to DT technologies and their relationships with the two pillars of sustainability. These barriers include low environmental regulations, wasted resources, lack of qualified human resources, lack of information sharing quality, lack of understanding of the interplay between technology and human beings, lack of collaboration between stakeholders, and lack of SC partners' awareness about social and environmental concerns and DT technologies.

Furthermore, the proposed study has also identified the DT adoption drivers, which are as follows: process improvement, workplace improvement, cleaner production, vertical and horizontal integrations, visibility, information sharing, sustainable technology capabilities, cost savings, waste and emissions reduction. Drivers can be viewed as external or internal enablers of why organizations embrace digital transformation [17,71]. Auto-adaptive systems handle the planning, control, and execution of production. Hence, the expected benefits include higher efficiency and reduced error rates. In addition, the use of disruptive technologies can ensure ergonomic work since robots perform complex and dangerous activities [71]. DT adoption can also improve manufacturing processes while minimizing breakdowns and setup times. This leads to reducing costs. Sensor technology collects data directly at the operational level and processes it for integration at the management level. The associated control information is returned through the hierarchy to the production systems [75,76]. With this information exchange, production-level planning can be more accurate, leading to running a wide range of products and production in smaller lots. Otherwise, the integration of various IT systems used in different SC functions and activities allows better exchange of materials, energy, and information within the supply chain system. Digital transformation serves the environmental pillar of sustainability, as it fundamentally involves optimizing resource consumption, energy efficiency, and waste and emissions reduction, thus enhancing SC profitability and effectiveness.

Tables 3 and 4 classify and rank key drivers and barriers to DT adoption for SSCs.

Table 3 Key drivers associated with DT adoption for SSCs

Rank	Drivers	Number of citations	Source
1	Information sharing	9	[1,2,25,32,36,40,48,66,76]
2	Visibility	8	[1,2,35,40,48,65,66,76]
3	Emissions reduction	7	[2,25,30,35,40,70,76]
4	Cost savings	6	[32,35,40,48,66,70]
	Waste reduction	6	[2,12,30,40,66,70]
5	Process improvement	5	[25,38,48,52,70]
	Cleaner production	5	[2,30,36,38,70]
	Sustainable technology capabilities	5	[1,30,40,70,76]
6	Workplace improvement	4	[15,25,38,52]
	Vertical integration	4	[12,25,34,36]
	Horizontal integration	4	[12,25,32,34]

Table 4 Key barriers to DT adoption for SSCs

Rank	Barriers	Number of citations	Source
1	Organizational barriers	14	[6,9,12,14,16,49,50,57,61,67,68,69,71,73]
	Technological barriers	14	[6,9,12,14,16,49,50,57,61,67,68,69,71,73]
2	Financial barriers	13	[6,9,12,14,16,49,50,61,67,68,69,71,73]
3	Social barriers	8	[6,12,50,57,67,68,69,71]
4	Environmental barriers	6	[6,9,12,49,50,67]
5	External barriers	4	[6,50,67,71]

6 Study implications

This study contributes to digital transformation and sustainable supply chain management research. Nonetheless, quantitative and qualitative studies on drivers and barriers to DT implementation for SSCs still need to be included. Firstly, both drivers and barriers have been selected from the current literature. The selected drivers and barriers may provide a roadmap for academia and policy-makers to comprehensively overview digital transformation implementation in the supply chain context. Manufacturing companies need to introduce suitable strategies to achieve a high level of success in the implementation. Findings reveal that decision-makers should consider the organizational, technological, financial, external, social, and environmental barriers before the DT implementation. However, manufacturing companies need to create and retain a sense of urgency as a first step in the digital transformation process, as many firms have already started implementing digital technologies in their business activities. Also, organizations should create a suitable environment that focuses on innovation, a culture of commitment, and a digital mindset at all decision-making levels. The results also argued that manufacturing companies require data scientists and analysts, as they can collect, refine and analyze data. In addition, digital transformation programs could only be successful with these skills. Digital security skills, mobile technology skills, blockchain, IoT, and cloud computing skills are also required for the digital transformation of firms. Therefore, manufacturing companies need to invest in specific training and hiring programs to enhance workforce skills and allow them to cope with new technologies and smart digital solutions. Otherwise, SC managers should promote the benefits of digital technologies and improve collaboration by improving the quality of information sharing among SC partners, focusing on organizational, technological, financial, external, social, and environmental barriers. IT units and organizations must jointly formulate sustainable and digital strategic plans to address all the opportunities to cope with all selected barriers and further achieve sustainability goals. This study is the first to identify the drivers and barriers to DT implementation in SSCs from a manufacturing context.

From the above discussion, a clear overview of drivers and barriers will allow manufacturing companies to realize the importance of addressing them. Therefore, they could start to take the abovementioned initiatives sequentially to fully develop the required capabilities for a sustainable and digitally enabled supply chain.

7 Conclusions

The present work aims to identify and discuss the key drivers and barriers to digital transformation adoption for sustainable supply chains from a manufacturing context. The adoption of DT is the main agenda for both developed and developing countries in the context of manufacturing. Current research has not tackled the taxonomy of DT drivers and barriers in SSCs from a manufacturing context. Therefore, this study was conducted in two stages to fill this gap. First, the authors have analyzed the past and current literature on DT and SSCs. This step was important for understanding the current status of digital technologies implementation in manufacturing supply chains. The second step was to select the critical drivers and barriers from previous studies. A total of six barriers and eleven drivers have been selected. A comprehensive grasp of DT dimensions is needed to shift to sustainable and digital supply chain systems successfully. The selected drivers can motivate manufacturing companies to shift supply chains from a classical level to a sustainable and digitally enabled one. Digital transformation program allows manufacturing companies to process improvement, workplace improvement, cleaner production, vertical and horizontal integrations, enhanced visibility, high level of information sharing, enhanced sustainable technology capabilities, cost savings, and waste and emissions reduction. A better understanding of the drivers allows manufacturing companies to proactively and positively shape the digital adoption process. However, DT barriers have been explored to mitigate the risk of implementation failure. These barriers have six dimensions: organizational, technological, financial, external, social, and environmental. Overcoming these roadblocks will increase the successful adoption of DT and, subsequently, the effectiveness and efficiency of supply chain systems.

However, this study had limitations that paved the way for future research directions. Firstly, this research could not be generalized, as it was devoted to the manufacturing sector. In addition, the selected barriers and drivers need to be checked by experts. Their insights and feedback can help to ensure the relevance and accuracy of the identified

drivers and barriers, thereby enhancing the overall quality and reliability of the study. This makes it challenging to generalize the obtained results. Future research could apply other potential unique techniques to select the key barriers and drivers, such as qualitative studies and direct interviews. Although the proposed paper is the first to identify the barriers and drivers of DT implementation in sustainable supply chains from the literature, quantitative studies are needed to prioritize key barriers, sub-barriers, and drivers and evaluate their cause-effect relationships. Thus, multi-criteria decision-making (MCDM) methods could be considered for this analysis. Moreover, a systematic approach is needed to identify key drivers and barriers, allocate available resources wisely, and create the environment necessary for sustainable and digital supply chain systems. Empirical evidence on ranking DT drivers and barriers and assessing their relationship should be carried out for both developed and developing countries. However, future studies need to be directed toward different sectors. In the future, DT adoption strategies for sustainable supply chains can be pinpointed and assessed using empirical research models such as small sample sizes using structural equation modeling (SEM). Furthermore, future conceptual frameworks and empirical evidence about the impact of digital transformation adoption and sustainable supply chain performance may be investigated to evaluate to what extent manufacturing firms could involve digital transformation technologies to improve their sustainable supply chain performance.

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Performance of Vietnamese shipping firms: a four random components stochastic frontier approach

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Keywords: technical efficiency, stochastic frontier analysis, Vietnamese shipping firms.
Abstract: This study aims to measure the overall technical efficiency score and analyze its determinants in the Vietnamese shipping industry. The data used in the study is the enterprise census data set collected by the General Statistics Office of Vietnam from 2016 to 2020. A major difference in this study compared to other empirical studies about the efficiency in Vietnam is that we applied the stochastic frontier analysis with four random components. The results of measuring efficiency scores show that: The average overall technical efficiency (OTE) score of Vietnamese shipping firms is 0.539. In which the persistent technical efficiency (PTE) score averaged 0.883 and the transitory technical efficiency (TTE) score averaged 0.60. It shows that the potential for operational efficiency of Vietnamese shipping firms is still very large. The results of the analysis of the determinants of OTE showed that. Internal firm characteristics such as firm size, firm age, return on equity of firm have a positive effect on OTE. And state-owned firms are less efficient than non-state firms. Besides, factors such as participation in international shipping, the quality of economic institutions also have a positive relationship with OTE. However, financial constraint, specifically the level of credit outstanding, is the main cause of slowing OTE growth.

1 Introduction

Ocean shipping plays an important role in the logistics service chain, and it is even more meaningful for countries with long coastlines like Vietnam. Well aware of this, the 12th Central Committee of the Communist Party of Vietnam issued Resolution 36-NQ/TW in 2018 on the strategy for sustainable development of the marine economy. This resolution emphasized that "By 2030, the shipping economy will take the second position in the development strategy of Vietnamese marine economic sectors, focusing on the effective exploitation of seaports and shipping services". And to do this, the Government has issued Resolution No. 26/NQ-CP on the master plan and 5-year plan in the strategy of sustainable development of Vietnamese marine economy to 2030, with a vision to 2045.

Over the years, the system of Vietnam's seaports has developed strongly and has received the world's largest tonnage ships to transport goods. Seaports meet the needs of ships entering and leaving the port, the waiting time for ships to dock at the port is short, well serving the clearance of import and export goods and goods transported domestically. Moreover, Vietnam is integrating deeply and widely into the world, as evidenced by new generation free trade agreements such as Comprehensive and Progressive Agreement for Trans-Pacific Partnership (CPTPP), European-Vietnam Free Trade Agreement (EVFTA), Regional Comprehensive Economic Partnership (RCEP) being signed and put into effect. Therefore, the volume of goods through Vietnamese seaports is growing. Specifically, the volume of goods through Vietnamese seaports reached 692 million tons in 2020, up 4% compared to 2019, of which container cargo reached 22.41 million TEUs, up 13% compared to 2019 [1]. This has been creating great advantages for the development of Vietnamese shipping firms.

Although Vietnamese shipping firms have experienced and significant growth over the years, this development is not commensurate with the role and position of Vietnam. The volume of goods imported and exported by sea in Vietnam is largely handled by foreign shipping lines. The international shipping market share of Vietnamese shipping firms tends to decrease, mainly exploiting short routes to China and countries in Southeast Asia. Sea transport routes to developed countries in Europe and America are almost impossible for domestic firms to undertake. Vietnam's international shipping vessels are still very limited in meeting the requirements of safety, maritime security and environmental protection, so many

ships are kept in foreign seaports. New-generation free trade agreements expand the transport market for Vietnamese fleets in other developed countries, but the domestic transport market will also have to open to foreign fleets. The services of transporting empty containers and consolidating goods for domestic seagoing vessels will face fierce competition, which may lead to Vietnamese shipping firms losing their domestic market share. In addition, the fleet structure of firms is not reasonable, small tonnage ships and bulk carriers account for a large proportion, large transport ships and container ships account for a very small number. Human resources of the shipping industry are lacking and weak in quality. On the other hand, with the achievements of the fourth technology revolution, the trend of applying technology to the logistics platform is accelerating and has a great impact on the efficiency of a supply chain [2]. However, the logistics platform of Vietnamese shipping industry is still weak and has not caught up with developed countries. The above factors will lead to low operational efficiency of Vietnamese shipping firms. The competitiveness of firms is not high, and it is difficult to win shipping contracts in the market.

Measuring efficiency at the firm level was suggested by [3], which uses concept of efficiency by [4] and radial efficiency measure by [5]. Efficiency measures can be divided into three different measures: technical efficiency (TE), allocative efficiency (AE) and economic efficiency (EE) [6]. In which, technical efficiency (TE) is the ability to minimize using inputs to produce a given output vector, or the ability to obtain maximum output from a given input vector. It reflects firms trying to avoid waste by optimally combining the inputs of the production process [6]. Besides, the identification of factors affecting technical efficiency is also a very important issue to identify the source of inefficiencies in production [7].

Stemming from the above reasons, this study aims to estimate the overall technical efficiency of Vietnamese shipping firms. At the same time, the study will construct and analyze the model of the factors that determine the technical efficiency of firms. The results of the study are an important scientific basis for planning new development policies for Vietnamese shipping industry.

2 Literature review and theoretical basis

2.1 Estimation of technical efficiency

Since its suggestion by [3], the measurement and analysis of technical efficiency has been of great interest to economists. Along with the development of computational techniques and the application of mathematics in economics, methods of measuring and analyzing technical efficiency have been strongly developed. Those methods are divided into two groups, namely parametric approach and non-parametric approach.

The non-parametric approach focuses on solving problems by maximizing or minimizing a given goal with some constraints. This approach uses linear programming techniques to find a set of weights for each firm that maximizes their relative efficiency score [8]. There are two techniques following the non-parametric approach: Data Envelopment Analysis (DEA) and Free Disposal Hull Approach (FDHA), in which DEA is the popular use. DEA measures technical efficiency by estimating the production frontier based on research data. The most effective combinations will lie on the frontier and TE is measured by the concept of the distance function from the frontier [6,9]. The concept of "data envelope analysis" was first used by [10]. From the idea [3] of the production frontier and the use of linear programming techniques in the analysis of isoquant curves, [10] developed a model to measure the efficiency of decision-making units (DMUs). They used the input-oriented distance function concept and assumed constant return to scale in this model. Several other studies have developed this method by removing the above assumptions [11]. The DEA builds the production frontier based on the data, so it does not need to make assumptions about the functional form or distribution of the efficiency factor. But the frontier of this method is very sensitive to dominant observations because it is made up of the most efficient combinations. Furthermore, the DEA does not take into account the influence of statistical noise. In order to overcome these limitations, [12] introduced the bootstrap technique to analyze the sampling characteristics, thereby obtaining the confidence intervals of the estimate. However, DEA still does not allow us to perform statistical tests and this is one of the biggest limitations of this method.

Meanwhile, the parametric approach uses maximum likelihood estimation techniques to compute the frontier function on a given sample [8]. With this approach, one needs to assume that all industries use the same technology and have the same production frontier. There are three main techniques in parameter frontier estimation, namely stochastic frontier analysis (SFA), thick frontier analysis (TFA) and distribution free analysis (DFA). Of these, the stochastic frontier analysis is most commonly used. SFA uses econometric models to estimate production frontiers and the technical efficiency corresponding to these frontiers. Although SFA requires imposing a specific parameter form for the common technology and assuming a specific distribution for the inefficiency term, it deals with random noise and allows for statistical testing of hypotheses regarding production structure and level of inefficiencies [13]. Thus, it becomes one of the most powerful techniques in technical efficiency measurement today. Since first independently introduced by [14] and [15], SFA has been developed through increasingly more advanced theoretical models. It is widely applied in efficiency and productivity research in various socio-economic fields such as: Agriculture [16], health care [17], tax [18], banking [19].

The basic stochastic frontier model is written by [14] as follows (1):

$$lny_i = f(x_i|\beta) + \varepsilon_i, (i = 1, \dots, n) \qquad (1)$$

where: $y_i \in \mathbb{R}_+^p$ is outputs, $x_i \in \mathbb{R}_+^l$ is inputs, and β is a vector of the parameters corresponding to x_i. The error term ε_i includes noise with standard distribution v_i representing measurement errors, and positive disturbance u_i with half-normal distribution that represents inefficiency (v_i and u_i independent), $\varepsilon_i = v_i - u_i$; $v_i \sim N(0, \sigma_v^2)$; $u_i \sim N^+(0, \sigma_u^2)$;. With the distribution assumptions on u_i and v_i, the likelihood function for the model is built and then the model is estimated by the maximum likelihood method.

However, the basic stochastic frontier model is built for cross sectional data, so there are certain limitations. This has been pointed out by [20] such as: Not exist consistent estimate of specific efficiency; Assume ineffective independence with the regression coefficients of the model; Requesting parametric distribution assumptions for ineffective and disturbance components to estimate the model. After that, many studies were conducted to solve these limitations. In particular, the special concern revolves around the advantage of panel data structure. In [20], authors are one of the first to develop theoretical framework to expand the stochastic frontier model for cross sectional data to a stochastic frontier model for panel data. But the technical efficiency is estimated by [20] which is time-invariant. This is a big limitation when applying the model to practice, especially for long panel data. [21] has overcome the model of [20] by constructing ineffective is the quadratic function of time variable. Meanwhile, the models of [16,22] allow the mean of inefficiency to change over time, but they are simpler because the time variable only depends on one or two parameters.

The above-mentioned panel data models have a big drawback that cannot be distinguished from technical efficiency with the unobserved individual heterogeneity. Therefore, the technical inefficiency confuses all time-invariant unobserved individual properties. There are many different approaches that have been proposed to overcome this problem. In [23], Greene has proposed a stochastic panel data model in which unobserved individual heterogeneity is distinct from technical efficiency. The model is built in the form as (2)

$$y_{it} = c_i + x_{it}'\beta + \varepsilon_{it} \text{ with } \varepsilon_{it} = v_{it} - u_{it} \quad (2)$$

where, v_{it} is disturbance, $u_{it} \geq 0$ is inefficiency.

Although model (2) distinguishes between unobserved individual heterogeneity and technical inefficiency, it only considers transitory inefficiency. In [24,25], the authors replaced model (2) with a model with four random components. In this model, inefficiency is decomposed into transitory inefficiency and persistent inefficiency. The model of [24] and [25] is written as follows:

$$y_{it} = \beta_0 + x_{it}'\beta + c_i - \eta_i + v_{it} - u_{it} \quad (3)$$

where: $c_i \sim N(0, \sigma_c^2)$ denotes the unobserved individual heterogeneity, $\eta_i \sim N(0, \sigma_c^2)$ denotes the persistent inefficiency, $u_{it} \sim N(0, \sigma_u^2)$ denotes transitory inefficiency, and $v_{it} \sim N(0, \sigma_v^2)$ is the regular disturbance. Model (3) can be estimated using the single-stage maximum likelihood method of [24] or the multi-step estimation procedure of [25]. Although the multi-step estimation procedure is not as efficient as the single-stage maximum likelihood method, it is simpler and easier to implement. For the multi-step estimation procedure, model (3) can be rewritten as

$$y_{it} = \beta_0^* + x_{it}'\beta + \alpha_i + \varepsilon_{it} \quad (4)$$

where:

$$\begin{aligned} \beta_0^* &= \beta_0 - E[\eta_i] - E[u_{it}]; \\ \alpha_i &= c_i - \eta_i + E(\eta_i); \\ \varepsilon_{it} &= v_{it} - u_{it} + E[u_{it}]. \end{aligned} \quad (5)$$

Model (4) is a standard panel data model and can be estimated by using typical panel data estimation method. After estimating (4), we get the predicted values $\widehat{\alpha_i}$, $\widehat{\varepsilon_{it}}$ of α_i and ε_{it}, these values are substituted for α_i and ε_{it} in (5). We then apply the standard stochastic frontier techniques for (5) to obtain the estimated values $\widehat{\eta_i}$, $\widehat{u_{it}}$ of η_i, u_{it}. Finally, persistent technical efficiency (PTE) is defined by $exp(-\widehat{\eta_i})$, transitory technical efficiency (TTE) derived from $exp(-u_{it})$, and overall technical efficiency (OTE) of the firm is defined by [25] as follows (6):

$$OTE = PTE * TTE \quad (6)$$

2.2 *Technical efficiency determinants*

In [7], Timmer applying a two-stage regression model to study the influence of factors on production efficiency argued that determining the level of technical efficiency is an important issue, but determining the origin of inefficiency is even more important. If the production factors of the firm grow steadily, the production process is optimized, the productivity and operational efficiency of the firm will be higher, and the cost of each output unit will decrease. This leads to improved competitiveness of the firm [26]. There are many factors that determine the technical efficiency of firms that have been shown by many studies. In this study, we group the factors according to some aspects such as the internal characteristics of the firm; international trade activities; financial constraints; and the quality of economic institutions.

Among the factors of firm characteristics, the factor recognized by many studies around the world is firm size. It is the means of production and business operation of firms. Firms which too large or too small can face management difficulties and create technical inefficiencies [27]. The expansion of firm scale is an industrial development trend and an inevitable result of competition

between firms. With a certain level of science and technology, firms can reduce long-term average costs by expanding production to achieve economies of scale [26]. Most studies show that firm size has a positive effect on firm performance [27-29]. However, there are also studies that show an inverse relationship between these two factors. In [30], Nikaido has shown a negative relationship between firm size and technical efficiency in small and medium firms. He explains the result that in some cases, small and medium firms often receive significant policy support from the government, so they have not been able to expand their scale. Next is the number of years of operation of the firms (firm age). The studies of [7,29] and [31] all show a close relationship between the age of a firm and its level of technical efficiency. In [27], authors argue that firm age positively affects production efficiency through learning by doing. Most studies argue that firms increasingly draw on experience to produce more efficiently. Therefore, older firms will have a higher level of efficiency. This is also supported by the study of [31] on Vietnamese manufacturing firms. However, authors in [27] also show that the marginal effect of this factor tends to decrease over time as firms mature in their field. This can also make the efficiency of the firm subject to the opposite effect of time. Moreover, recent empirical evidence shows that young firms produce more efficiently than older ones. This can be explained by the fact that young firms embody the latest technology and the technological wear and tear of older firms [32]. In addition, there are a number of other factors such as the type of firm ownership, the rate of return on equity, etc., which have also been mentioned by the studies [28].

Besides, there have been a lot of empirical studies related to international trade activities, especially import and export activities with the performance of firms [33]. There are two hypotheses to explain the relationship between international trade and firm performance, namely the self-selection hypothesis and the learning by doing hypothesis. The self-selection hypothesis holds that only the most productive firms decide to enter international markets [33,34]. The learning by doing hypothesis argues that firms in international markets can take advantage of economies of scale and gain knowledge from greater exposure to best practices, from which promotes the productivity and performance of the firm [35].

Access to credit will facilitate long-term investment, reduce volatility and improve firm productivity [36]. At the same time, one of the biggest barriers to firm survival and expansion is access to credit, especially for small and medium-sized firms. Evaluation of the impact of debt balance on the efficiency of firms has been conducted by many studies. However, the results follow different trends, most studies show a positive impact of debt balance on firm efficiency [37]. The explanation for this positive relationship is that debt allows firms to export and import inputs and means of production. It drives firms to scale, make technological improvements, and invest in R&D and other tools needed to increase productivity. Meanwhile, [38] finds a negative relationship between debt balance and firm performance. It can be seen from the [39] that debt balance has a positive effect on firm performance at a certain debt level (threshold debt level) and this effect becomes negative when this threshold debt level is reached.

The important role of economic institutions for development has been shown in previous studies. The results show that economic institutions have a direct impact on economic efficiency in the same period and resource distribution in the following period [40]. The economic institution contributes to the performance of firms by creating favorable conditions for firms to produce or to direct their activities. If the quality of institutions is good, there will be no informal costs, reliable legal institutions, strong enforcement of property rights and will have a positive impact on the productivity and growth of firms. In contrast, poor institutional quality makes it difficult to enforce contracts, so paying bribes is necessary. And it will increase the operating costs of firms, giving firms an incentive to absorb ineffective technologies for the production process rather than absorb modern technology [41]. Most recent research results show a positive impact of the quality of economic institutions on the efficiency and productivity of firms [42,43].

3 Methodology and data

The study uses the SFA model of [25] to estimate the overall technical efficiency for Vietnamese shipping firms. The frontier production function of firms can be estimated in both Cobb-Douglas and Translog forms. Applying equations (3) and (4), we can rewrite the frontier production function for Vietnamese shipping firms as follows (7), (8), (9), (10):

Cobb-Douglas form

$$Ln(VA_{it}) = \beta_0 + \beta_1.LnK_{it} + \beta_2.LnL_{it} + \beta_3.t + c_i - \eta_i + v_{it} - u_{it} \quad (7)$$

or

$$Ln(VA_{it}) = \beta_0 + \beta_1.LnK_{it} + \beta_2.LnL_{it} + \beta_3.t + \alpha_i + \varepsilon_{it} \quad (8)$$

Translog form

$$lnVA_{it} = \beta_0 + \beta_1 lnK_{it} + \beta_2 lnL_{it} + \beta_3.t + \frac{1}{2}\beta_4(lnK_{it})^2 + \frac{1}{2}\beta_5(lnL_{it})^2 + \frac{1}{2}\beta_6 t^2 + \frac{1}{2}\beta_7 lnK_{it}.lnL_{it} + \frac{1}{2}\beta_8 t.lnK_{it} + \frac{1}{2}\beta_9 t.lnL_{it} + c_i - \eta_i + v_{it} - u_{it} \quad (9)$$

or

$$lnVA_{it} = \beta_0 + \beta_1 lnK_{it} + \beta_2 lnL_{it} + \beta_3 t + \frac{1}{2}\beta_4(lnK_{it})^2 + \frac{1}{2}\beta_5(lnL_{it})^2 + \frac{1}{2}\beta_6 t^2 + \frac{1}{2}\beta_7 lnK_{it}.lnL_{it} + \frac{1}{2}\beta_8 t.lnK_{it} + \frac{1}{2}\beta_9 t.lnL_{it} + \alpha_i + \varepsilon_{it} \quad (10)$$

where:

VA_{it} is the output, K_{it} and L_{it} are the two inputs of the i^{th} firm at time *t*.

The study uses the generalized likelihood ratio (LR) test to select the form of the frontier production function suitable to the data, the value of the LR test is calculated as follows (11):

$$LR = -2\{log[L(H_0)] - log[L(H_1)]\} \quad (11)$$

where:

$L(H_0), L(H_1)$ are the values of the rational function estimated in Cobb-Douglas and Translog form, respectively. If LR is less than the value of $\chi^2_{-Critical}$ obtained from the table Kodde & Palm [44], then choose the Cobb-Douglas function. Otherwise, we choose the Translog production function.

The PTE, TTE values are predicted after estimating the frontier production function using the multi-step estimation procedure of [25]. And from there we get OTE of Vietnamese shipping firms.

However, measuring efficiency is only an early stage, and it is important for this study to determine the influence of exogenous factors on performance differences between firms. Because the value of the dependent variable OTE is in the [0,1] (censored sample), if we use the OLS method to analyze the model, it will lead to the estimated results of the parameters may be biased and not consistent. Instead, we use Tobit regression to estimate the impact of the independent variables on the overall technical efficiency score [45]. On the basis of the theory on the impact of factors on the efficiency of firms presented above, the study constructs a model of some factors that determine the technical efficiency of Vietnamese shipping firms, as follows (12):

$$OTE_{it} = \alpha_0 + \alpha_1.lnK_{it} + \alpha_2.lnAge_{it} + \alpha_3.lnRoe_{it} + \alpha_4.Ownership_{it} + \alpha_5.Intertrate_{it} + \alpha_6.lnDte_{it} + + \alpha_7.lnPci_{it} + \varepsilon_{it} \quad (12)$$

where, overall technical efficiency (*OTE*) is the dependent variable. The independent variables include: Variables belonging to the characteristics of the firm such as firm size (*lnK*, natural logarithm of total assets), the natural logarithm of firm age (*lnAge*), return on equity (Roe), type of firm ownership (*Ownership*); Variable on international trade activities (Intertrade); The variable on debt balance (*lnDte*), is taken as the natural logarithm; And the variable on the quality of economic institutions (*lnPci*), is also taken as the natural logarithm. The meanings and measurements of these variables are presented in Table 1.

The literature review also shows that many empirical studies have focused on analyzing the relationship between research and development (R&D), innovation and firm performance [46]. However, due to data limitations, our study has not mentioned these factors.

The data for this study are secondary data about Vietnamese ocean shipping firms, collected by the General Statistics Office of Vietnam. And provincial competitiveness index data, collected by the Vietnam Chamber of Commerce and Industry. The data are collected in the years from 2016 to 2020. We calculate to get data for the variables in the technical efficiency estimation model and the model of factors affecting it in each year. Finally, we merge the data of the years to get a sample for Vietnamese shipping firms. The sample obtained is the balanced panel data of 78 firms for 5 years (390 observations), measurement and descriptive statistics of the variables are presented in Table 1.

Table 1 Definition and descriptive statistics of variables

Variables	***Definition***	***Obs***	***Mean***	***SD***
VA	Value added of the firm in the year (calculated at constant prices in 2010)	390	29047.360	83575.650
K	Total assets at the end of the year of the firm (calculated at constant prices in 2010)	390	126798.300	287064.500
L	Total number of full-time employees in the year of the firm	390	47.174	64.789
t	Year of study (from 1 to 5)	390	3.000	1.416
lnVA	Is the natural logarithm of VA	390	8.418	1.565
lnK	Is the natural logarithm of K	390	10.065	1.533
lnL	Is the natural logarithm of L	390	3.284	1.035
lnAge	Calculated by the natural logarithm of the firm age	390	1.926	0.567
Roe	Calculated by profit after indirect tax / Equity	390	0.415	0.493
Ownership	Is a dummy variable that takes the value of 1 if it is a state-owned firm and otherwise takes the value of 0.	390	0.070	1.800
Intertrade	Is a dummy variable that takes the value of 1 if the firm has international shipping in the year, otherwise it is equal to 0	390	0.315	0.465
lnDte	Calculated as the natural logarithm of total debt / equity	390	1.097	0.976
lnPci	Calculated by the natural logarithm of the provincial competitiveness index in Vietnam	390	4.161	0.053

4 Empirical results

We conduct the generalized likelihood ratio test for the sample with the null hypothesis "The frontier production function follows the Cobb-Douglas form". The test results show that the value of LR is 18.020 is smaller than the value of $\chi^2_{-Critical}$ is 21.666 at a significant level of 1%. Therefore, there is not enough evidence to reject the null hypothesis, so the Cobb-Douglas production function form is chosen. And the results of the frontier production function model for Vietnamese shipping firms are presented in Table 2. We see that the estimated coefficients are statistically significant and in accordance with economic theory. In which, the elasticity of capital relative to output is quite large (0.548) and is close to the elasticity of labor relative to output. This indicates a significant contribution of capital to output and no labor intensiveness in firms. The sum of these two elasticity coefficients is greater than 1, indicating that firms are increasing return to scale. Besides, the estimated coefficient of the time variable is 0.178, which implies that the contribution of technological progress to the productivity growth of firms reaching an average of 17.8 % of the year [16].

Table 2 Estimation results of frontier production function of Vietnamese shipping firms in the period from 2016 to 2020

Variable	***Coef.***	***Std. Err.***	***z***	***P>|z|***
LnK	0.548***	0.039	14.100	0.000
LnL	0.578***	0.057	10.080	0.000
t	0.178***	0.024	7.540	0.000
_cons	1.157***	0.265	4.370	0.000

Note: ***, ** and * indicates significant at 1%, 5% and 10% level of significance

After estimating the frontier production function of firms, we predict the persistent technical efficiency (PTE), transitory technical efficiency (TTE) and overall technical efficiency (OTE) of firms. The results of PTE, TTE and OTE are presented in Table 3. We see that the average overall technical efficiency (OTE) of firms reached 0.539, of which persistent technical efficiency (PTE) reaching an average of 0.883 and transitory technical efficiency (TTE) reaches an average of 0.607 in the period from 2016 to 2020. This shows that the room for efficiency in production of Vietnamese shipping firms is still very large, especially TTE. On the other hand, the standard deviation of OTE is still large and there is no decline during the research period, showing a large gap in the performance of firms. However, there is a good sign when considering the histogram and the kernel density of the OTE of firms described in Figure 1. Most firms have an OTE score close to the average of the whole industry and the proportion of firms with OTE larger than the average greater than the proportion of firms with OTE smaller than the average.

Table 3 Performance of Vietnamese shipping firms in the period from 2016 to 2020

Year	***Variable***	***Obs***	***Mean***	***Std. Dev.***	***Min***	***Max***
2016	*PTE*	78	0.883	0.048	0.695	0.955
	TTE	78	0.664	0.117	0.355	0.866
	OTE	78	0.588	0.112	0.316	0.817
2017	*PTE*	78	0.883	0.048	0.695	0.955
	TTE	78	0.566	0.147	0.253	0.839
	OTE	78	0.502	0.140	0.206	0.783
2018	*PTE*	78	0.883	0.048	0.695	0.955
	TTE	78	0.535	0.131	0.241	0.856
	OTE	78	0.474	0.126	0.210	0.790
2019	*PTE*	78	0.883	0.048	0.695	0.955
	TTE	78	0.631	0.149	0.206	0.833
	OTE	78	0.561	0.145	0.179	0.772
2020	*PTE*	78	0.883	0.048	0.695	0.955
	TTE	78	0.640	0.168	0.060	0.860
	OTE	78	0.569	0.163	0.049	0.776

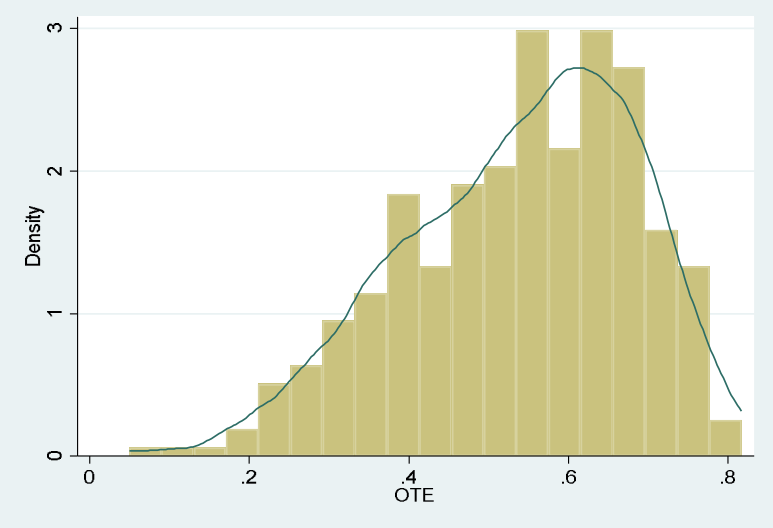

Figure 1 Histogram and Kernel density of the OTE (own editing)

The distribution of OTE of firms over the years showed a picture that did not flourish the performance of Vietnamese shipping firms in recent years. OTE of firms not only without growth during the research period but also seriously decreased in 2017 and 2018. This shows that firms do not have the optimal combination of inputs to improve their output. It reflects the current production situation of Vietnamese shipping firms today. Firms mainly exploit bulk ships and general cargo ships in order to save investment and easy to operate, so the production efficiency is not high. Ships that bring high added value such as container ships, liquefied gas tankers account for a very small proportion in the fleet structure of firms. The fleet quality in firms is weak in terms of technical equipment and operating level. Most of the ships are old, so maintenance costs are high to meet the requirements of international maritime conventions, and operating skills of crews are still limited. In addition, firms are still limited in updating information about the situation of shipping, goods demand, and related policies. These factors are the fundamental cause of constraining the technical efficiency of Vietnamese shipping firms today.

Next, we conduct an analysis of the factors that determine the technical efficiency of Vietnamese shipping firms. Before estimating the model (12), we tested the multicollinearity between the independent variables by analyzing the variance inflation factors (VIF). The estimation results presented in Table 4 show that all VIFs are less than 2, so there is no evidence of multicollinearity. Therefore, the selected variables in the model (12) are suitable.

Table 4 The variance inflation factors of the independent variables

Variables	**VIF**	**1/VIF**
lnK	1.800	0.555
Intertrade	1.780	0.562
lnAge	1.240	0.807
lnpci	1.140	0.874
lnDte	1.140	0.876
Ownership	1.040	0.959
Roe	1.030	0.970
Mean VIF	**1.310**	

Table 5 Estimation results of factors affecting the technical efficiency of Vietnamese shipping firms

OTE	***Coef.***	***Std. Err.***	***t***	***P>|t|***
lnK	0.009***	0.002	3.78	0.000
lnAge	0.016***	0.004	3.69	0.000
Ownership	-0.013**	0.006	-2.39	0.017
Roe	0.005***	0.001	4.11	0.000
Intertrade	0.047**	0.021	2.25	0.025
lnDte	-0.001**	0.000	-2.13	0.034
lnPci	0.014***	0.005	2.82	0.005
_cons	-1.159**	0.516	-2.24	0.026

Note: ***, ** and * indicates significant at 1%, 5% and 10% level of significance

Table 5 presents the results of estimation of the factors determining the technical efficiency of Vietnamese shipping industry. According to the internal characteristics of the firm, the coefficients of the variables *lnK*, *lnAge* are all positive and have statistical significance at 1% level. And when these variables increase by 1%, the technical efficiency of Vietnamese shipping firms increases by 0.009% and 0.016%, respectively. This shows that firms benefit significantly from economies of scale. And older firms produce more efficiently than younger firms. It implies that working experience plays an important role and has a positive impact on the performance of Vietnamese shipping firms. These results are also similar to the work of [31] for Vietnamese manufacturing firms. Along with that is the positive impact of the return on equity on the technical efficiency of firms. It shows that the ability to manage and use capital of firm owners is one of the decisive factors to the performance of the firm. In addition, the estimation results of the *Ownership* variable show that state-owned shipping firms operate less efficiently than non-state firms. In fact, some state-owned shipping firms in Vietnam are assigned a large amount of assets for production, but the management and supervision systems are still weak and do not keep up with practical requirements. Moreover, these firms have not encouraged employees, and have not paid attention to the responsibility of the head for the performance of the firms. These make them inefficient in production, at risk of business losses, and loss of state capital.

Regarding international trade activities, the results show that this factor has a positive relationship with technical efficiency. That is, firms participating in international shipping will achieve higher efficiency than firms only in domestic shipping. This shows that Vietnamese shipping firms have taken advantage of economies of scale and learned best practices when participating in international shipping activities. It is consistent with the argument that international trade is a complementary factor to increase the productivity and efficiency of the firm [47].

The estimated results also show the negative impact of financial constraints on the performance of firms. If the credit balance of firms increases by 1%, the technical efficiency score will decrease by -0.001% at 5% significance level. This result shows that Vietnamese shipping firms may have surpassed the debt threshold and it is the cause of inhibiting their performances.

Regarding the quality of economic institutions, the research results show the positive impact of this factor on the performance of firms in Vietnamese shipping industry. Over the years, the state has issued many legal documents guiding the Vietnam Maritime Code, contributing to strengthening the legal corridor and facilitating the development of shipping. These include policies related to ships, crew members, and infrastructure for shipping. Along with that, the quality of economic management, business convenience, and administrative reform efforts of local governments in Vietnam have always been improved. These have had a great impact on the performance of enterprises in general and the shipping industry in particular.

5 Conclusions

This study applies the four random component SFA model and the Tobit regression model in order to not only evaluate the performance of Vietnamese shipping firms but also analyze the combination of factors affecting can improve this efficiency. The research results have shown that: The overall technical efficiency (OTE) of Vietnamese shipping industry from 2016 to 2020 averaged 47.4% to 58.8%. In which, persistent technical efficiency (PTE) averaged 88.3%, while transitory technical efficiency (TTE) averaged from 53.5% to 66.4%. This result implies that on average a Vietnamese shipping firm suffers an overall level of technical inefficiencies between 41.2% and 52.6%. For the factors that determine the technical efficiency of firms, the estimated results show that. Firm size, firm age, return on equity, and international shipping are positively related to the OTE of firms. Meanwhile, factors such as credit balance and state-owned have a negative relationship with OTE. From the research results, we make some recommendations to promote the performance of Vietnamese shipping industry as follows:

Management and production technology in firms need to be continuously optimized to enhance the contribution of TTE to OTE. Firms with low efficiency scores need to expand their scale, especially when it comes to participating in international shipping activities. At the same time, the quality of governance in these firms also needs to be improved to catch up with those with high technical efficiency scores. In addition, Vietnamese shipping firms can apply different development routes depending on the conditions of each firm to improve their performance.

The government needs to continue to have better financial policies in supporting firms to develop large tonnage fleets to replace the current small and old fleets. At the same time, firms should be supported to develop specialized fleets such as container ships, oil tankers, liquefied gas tankers, etc., so that firms can achieve better operational efficiency. Those policies should be concretized, such as: Exemption of import tax for firms that replace old ships with new ships or ships with larger tonnage or ships with specialized ships; Reduce tonnage fees for a certain period of time when firms put into operation container ships, liquefied gas tankers, and clean energy ships; Reduce corporate income tax and other fees when Vietnamese shipping firms have a large monthly import and export container volume or have long-term transportation contracts with foreign partners.

The government should step up administrative reform in the field of shipping, simplify administrative procedures, especially those in ship registration and procedures at seaports. Continue to review, amend and supplement

Vietnamese legal document system on shipping, creating a stable and favorable legal corridor to support firms to operate effectively. Promote digital transformation in seaports, customs, etc. so that firms can reduce time costs. Actively participate in international conventions on maritime, promote international cooperation in shipping, support in legal procedures for firms opening shipping services abroad. Along with that, local authorities need to be transparent in the implementation of policies, creating favorable conditions for production and business of firms.

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Sources of sustainable competitive advantage and direction of development: a study on pharmaceutical SMEs
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Sources of sustainable competitive advantage and direction of development: a study on pharmaceutical SMEs

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Keywords: **s**ustainable competitive advantage (SCA), small and medium-sized enterprises (SMEs), sense & respond, operations strategy, southern Vietnam.
Abstract: To cope, preserve market position, and achieve sustainable competitive advantage (SCA), companies should put operations strategy into action systematically and coherently. In this vein, the purpose of this study is to evaluate small and medium-sized (SME) pharmaceutical firms in southern Vietnam considering their current strategic orientation, development path, and sustanability of competitive advantage. The method used in this research is Sense and Respond (S&R), supported with combination of different tools. The data has been gathered from six companies utilizing two questionnaires: "Manufacturing strategy index (MSI)" and "S&R". The results show that, all case companies act as Analyzer both in the past and in the future when employing operations strategy. In all case companies, quality found to be the most important competitive priority in the past and future, and the main source of competitive advantage. Furthermore, spearhead technology and knowledge (T&K) found to be the main source of risk in operations strategy and SCA. The Weak Market Test demonstrates that the research results are consistent with the actual situations of the case companies. The research concludes that S&R method works well in evaluating the operative SCA of pharmaceutical SMEs.

1 Introduction

During the past decade, many studies have presented the considerable influence of market turbulence on the business world. In addition, due to the ongoing Covid-19 crisis, the changes and precariousness have been greatly accelerated [1]. Thus, to position themselves against the competition, companies should put operations strategy into action systematically and coherently, and more specifically, should create and develop a sustainable competitive advantage [2,3]. The concept of sustainable competitive advantage (SCA) was introduced by Porter in his pioneering books (1980, 1985) [c.f. 4] and it has since progressively developed. For example, SCA has been introduced as a resource-based theory which explains heterogeneously distributed resources and capabilities are the sources of SCA and the reason why certain companies consistently outperform others [5].

Businesses, especially SMEs, are struggling more than ever, both in terms of increasing competition in the market and responding to the needs of an ever-changing business environment [6]. In Vietnam, as an illustration, the healthcare market in general and the pharmaceutical industry specifically are growing rapidly [7] along with a shift in demand for medical goods driven by the Covid-19 pandemic [8]. As a result, to be able to compete in the large marketplace, pharmaceutical SMEs need to develop an effective competitive operations strategy. A similar suggestion has been made in the previous study, in order to remain competitive in the marketplace, companies should seek out the best approaches to match the requirements of a fast-changing business environment [9]. Despite the fact that it is right, the majority of pharmaceutical companies in Vietnam have yet to focus on developing a comprehensive development strategy [10] and there is currently no specific master plan for the long-term growth of Vietnam's pharmaceutical industry [11]. Furthermore, the authors concluded that research on the pharmaceutical industry in Vietnam has so far been fairly limited. As a result, the purpose of this article is to evaluate the sustainable competitive advantage of pharmaceutical SMEs in southern Vietnam in terms of their present orientation, development of strategy, and sustainability. The paper, on the other hand, may benefit pharmaceutical businesses by assisting decision-makers in better comprehending business climates and reacting more accurately and effectively in the turbulent business world.

To meet these objectives, this research tries to answer the following two questions:

1. What are the sources of pharmaceutical SMEs' competitive advantages and direction of development?
2. How sustainable is the pharmaceutical SMEs' operations strategy?

In this research, SCA is evaluated based on the Manufacturing strategy index (MSI) and Sense and respond methodology, integrated with various models and tools, such as Analytic hierarchy process (AHP), Critical factor indexes (CFIs), and Technology & Knowledge

(T&K) ranking and risk levels [2]. T&K is taken into account when evaluating SCA levels as it plays a big role in a company's value chain and can help businesses reduce costs and differentiate themselves from competitors [2,12].

The paper begins with an introduction of the theoretical background, methodologies, and tools connected to the researched topic, followed by the information regarding case companies, data collection procedures, and data analysis. The results are then offered. Finally, the discussion and conclusions are presented.

2 Theoretical background

2.1. Manufacturing strategy

Manufacturing strategy is described as a long-term plan of manufacturing decision-making which is compatible with the overall strategy of the company [13]. Strategy, accordingly, is interpreted as "a pattern or plan that integrates an organization's major goals, policies, and action sequences into a cohesive whole" [14, p.10]. Miles and Snow's strategy typology is a fundamental tool for analyzing different types of strategies based on external and internal dependent elements [15]. According to this typology, there are four categories of business strategy: Prospector, Analyzer, Defender, and Reactor, as shown below [16]:

- ***Prospector*** concentrates on innovative product development and actively looks for new product-market possibilities. Prospector's strategic priority lies in Quality.
- ***Defender*** puts emphasis on improving the efficiency of current operations and attempts to keep its market share. Defender's strategic priority lies in Cost.
- ***Analyzer*** combines elements of Prospector and Defender. Analyzer attempts to adjust to new market or industry developments while preserving its market position. Analyzer's strategic priority lies in Quality, Cost, and Time.
- ***Reactor*** concentrates on everything at once in an effort to adapt to the constantly shifting business environment; therefore, Reactor exhibits no strategic priority.

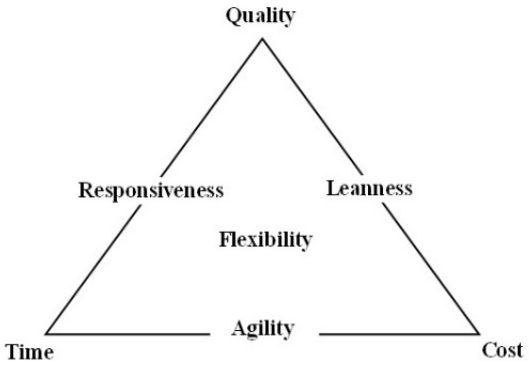

Figure 1 RAL model [23]

A successful manufacturing strategy is said to be created by identifying competitive priorities, which serve as a link between competitive strategy and manufacturing goals [17-19]. Previous studies have stated that the RAL (Responsiveness, Agility, and Leanness, see Figure 1) model has been used effectively to determine strategic priorities [20-22].

2.2. AHP, sense and respond, CFIs

The Analytical hierarchy process (AHP) is a decision-making method within multiple criteria. To use AHP in practice the decision makers are required to compare the importance of criteria, two at a time, and make a pairwise comparison between the decision variables considering relative importance on the scale of 1 to 9. Here, 1 indicates that both criteria are similarly important, whereas 9 indicates that one criteria is absolutely crucial over the other. In fact, AHP method helps to convert decision maker's evaluation into numbers that can be compared with the decision-making variables and finally, decision-maker set priorities and select the optimal choice among decision criteria [24].

Sense and respond methodology was introduced by Haeckel in 1992, then further developed by Bradley and Nolan in 1998, and later in 2000, Markides utilized it as the primary research method for studying dynamic business strategies [c.f. 25]. S&R methodology aims to provide a way to tackle the issues posed by disruptions or changes in a continuous process [26]. To put it another way, S&R method is used to assist with flexible decision-making by characterizing, assessing, benchmarking, and optimizing the allocation of resources to fulfill performance needs both inside and outside the firm [2].

The Critical factor index (CFI) method is a measurement instrument that identifies which process attributes are crucial and which are not, as claimed by the experience and expectations of the respondents [27]. The CFI model has been developed in three stages, which are known as the Balanced critical factor index (BCFI) model, the Scaled critical factor index (SCFI) model, and the New scaled critical factor index (NSCFI) model [2]. In this paper, NSCFI is employed to assess the business performance of the companies, as it outperforms the previous models in terms of accuracy and stability [22].

Additionally, a total of 21 attributes are used to define the technology & knowledge management, processes & work flow, organizational system, and information systems of the case companies [22]. In the Results section, the attributes are presented as numbers. The detailed names of each attribute can be found in Appendix 1.

2.3. SCA risk level

Sustainable competitive advantage (SCA) is a measurement of the level of risk at which the operations strategy needs to be enhanced so that companies can maintain operative competitiveness during the time period in question [2]. Three indicators are employed in this study

to measure the level of risk of the operations strategy over the long term, they are Mean absolute percentage error (MAPE), Root means squared error (RMSE), and Mean absolute deviation (MAD). The threshold value for the SCA risk level is 0.9 [20]. Closer the SCA risk level to 1 higher the consistency between the allocation of resources and operations strategy.

2.4. Technology & Knowledge ranking and risk levels

As a company's resources are not infinite, it is vital to determine a technology priority which is connected to its business strategy and can deliver a competitive edge and profitability. Technology is one of the key factors of completion and it turns into essential if it enables businesses to minimize costs, create differentiation, and increase product quality [28]. Furthermore, sustainable competitive advantages are primarily based on knowledge, which indicates that figuring out ways to do things is equally important as possessing access to specialized resources when establishing a value chain [29]. Therefore, to obtain information about the technology and knowledge rankings of a company, technology and knowledge requirements are included in the S&R questionnaire [2].

To evaluate the effect of knowledge and technology on a company's business strategy, each attribute related to the basic, core, and spearhead technologies is estimated as a percentage by respondents, with the total of all three being 100% [2]. Here, basic refers to the technology and knowledge that is most essential to the operation of a business, while core refers to company-specific technology and knowledge, and the spearhead is closely related to the future requirements of technology and knowledge. Risk levels then are calculated to identify which type of technology brings the most uncertainty to a company.

3 Materials and methods

3.1. Case introduction

The southern market in Vietnam has been identified as the greatest drug consumption market, and Ho Chi Minh is the primary municipality in southern Vietnam, consuming up to 55% of the country's drug products [30]. Therefore, this study considers the pharmaceutical SMEs from this region i.e. the case companies considered in this research has offices or principal operations in Ho Chi Minh City. These companies, in particular, have been in operation for 4-8 years, and their core businesses include retailing drugs, cosmetics, medical equipment, and hygiene items. Furthermore, some companies offer packing, drug storage, and testing services.

3.2. Data collection procedure

This research is conducted based on six pharmaceutical companies from southern Vietnam, and two representatives of each company join the interview. The interviewees are the middle or top managers, who thoroughly understand their companies' operations. The interviews are carried out via audio and video calls over the internet. The data are gathered utilizing two separate questionnaires: one relating to the Manufacturing strategy index (see Appendix 2) and another for the Sense and respond method (see Appendix 1). In the end, the Weak market test (WMT) is applied to assess the extent to which the obtained results relate to the real situations of the companies.

3.3. Methods of data analysis

The collected data are analyzed following the six steps, mentioned below:

Step 1: Find a case company and informant, and collect necessary data following MSI and S&R questionnaires.

In this step, it is very important to consider at least two respondents from the top or middle management level who has the good understanding of operations strategies of the case company and the business environment.

Step 2: Obtain parameters for MSI i.e. determine the criteria weight following the AHP method.

In this step, data are collected for the MSI questionnaire (see Appendix 2) and the criteria weight are determined by AHP method.

Step 3: Calculate values of critical factor indexes (CFIs) and evaluate resource allocations.

The resource allocations can be evaluated by following any of the methods: CFI, BCFI, SCFI, or NSCFI. However, in this study, the NSCFI model has been used to evaluate resource allocations, this is simply because NSCFI is the latest model that provides higher accuracy and stability than other models [22].

NSCFI is calculated using the following equation:

$$NSCFI = \frac{\sqrt{\frac{1}{n}*\sum_{i=1}^{n}[experience(i)]^2}*\sqrt{\frac{1}{n}*\sum_{i=1}^{n}[expectation(i)-11]^2}*Performance\ Index}{Gap\ Index'*Development\ Index'*Importance\ Index} \quad (1)$$

Here,

$$Importance\ Index = \frac{Average\ of\ expectation}{10} \quad (2)$$

$$Performance\ Index = \frac{Average\ of\ experience}{10} \quad (3)$$

$$Gap\ Index' = 2^{\frac{Avg(expectations)-Avg(experience)}{10}} \quad (4)$$

$$Development\ Index' = 2^{(worse\%-better\%)} \quad (5)$$

Sources of equations in step 3 are [31, 32].

An attribute is considered to be under-resourced if its CFIs value is less than one-third of the average resource level, and it is considered to be over-resourced if its level exceeds two-thirds of the average resource level. The optimal situation occurs when attributes are in the range of one-third to two-thirds of the average resource level i.e. the attributes are considered balanced [22].

In other words,

$$\text{Average resource level} = \frac{1}{21} \approx 0.047619$$

Here, the idea is that the total resource input is 1 which has been divided into 21 different portions.

$$\text{Under-resourced level} = \frac{2}{3} * \text{Average resource level} \approx 0.032$$

$$\text{Over-resourced level} = \frac{4}{3} * \text{Average resource level} \approx 0.063$$

Any resource value between 0.032 and 0.063 is considered to be optimum resource situation.

Step 4: Calculate Manufacturing strategy index (MSI) values and detect the strategic orientation.

To identify the strategy type adopted by a company, MSI uses Responsive, Agility and Leanness (RAL) model [23] (see Figure 1). Responsiveness means how quickly the system responds to unexpected requirements, Agility means how quickly the system adjusts to the ideal cost structure, and Leanness means to the elimination of waste in all resources and operations. The four elements of the RAL-model are Quality, Cost, Time, and Flexibility. An example to RAL model/MSI triangle is shown in Figure 1.

To identify the strategic orientation, following formulas are used.

The MSI model for Prospector is as follows:

$$MSI_P = 1 - \left[\left(1 - (Q')^{\frac{1}{3}}\right) * (1 - 0.9 * T') * (1 - 0.9 * C') * (F')^{\frac{1}{3}}\right] \quad (6)$$

The MSI model for Defender is as follows:

$$MSI_D = 1 - \left[\left(1 - (C')^{\frac{1}{3}}\right) * (1 - 0.9 * T') * (1 - 0.9 * Q') * (F')^{\frac{1}{3}}\right] \quad (7)$$

The MSI model for Analyzer is as follows:

$$MSI_A = 1 - \left[(1 - F') * \left[ABS[(0.95 * Q' - 0.285) * (0.95 * T' - 0.285) * (0.95 * C' - 0.285)]\right]^{\frac{1}{3}}\right] \quad (8)$$

Here,

$$C' = \frac{C}{Q+C+T} \quad (9)$$

$$Q' = \frac{Q}{Q+C+T} \quad (10)$$

$$T' = \frac{T}{Q+C+T} \quad (11)$$

$$F' = \frac{F}{Q+C+T+F} \quad (12)$$

Furtheremore, in equations 9, 10, 11, and 12, C is cost, Q is quality, T is time/delivery, and F is flexibility.

Sources of equations in step 4 are [31,32].

Step 5: Calculate the parameters for sustainable competitive advantage (SCA) level and evaluate SCA risks.

The SCA risk levels are identified in different methods: Mean absolute percentage error (MAPE), Root means squared error (RMSE) and Mean absolute deviation (MAD). The formulas of these three methods are shown below:

Mean absolute percentage error (MAPE):

$$SCA\ risk\ level\ following\ MAPE\ measure = 1 - \sum_{\alpha,\beta,\gamma} \left|\frac{BS-BR}{BS}\right| \quad (13)$$

Root means squared error (RMSE):

$$SCA\ risk\ level\ following\ RMSE\ measure = 1 - \left(\sum_{\alpha,\beta,\gamma} \left(\frac{BS-BR}{BS}\right)^2\right)^{\frac{1}{2}} \quad (14)$$

Mean absolute deviation (MAD):

$$SCA\ risk\ level\ following\ MAD\ measure = 1 - max_{\alpha,\beta,\gamma}\left|\frac{BS-BR}{BS}\right| \quad (15)$$

Where BS is the result of MSI and BR is the results of CFIs. Both BS and BR are the angles in radians. Here, BS represents the angles of MSI triangle formed by MSI values (calculated considering MSI questionnaire, see Appendix 2) and BR represents the angles of MSI triangle formed by MSI values (calculated from CFIs considering S&R questionnaire, see Appendix 1).

Sources of equations in step 5 are [12,33].

Step 6: Calculate and analyse technology and knowledge risks ($T\&K_{RISK}$).

Sixth step in implementing S&R in practice is to calculate the technology and knowledge risks ($T\&K_{RISK}$). $T\&K_{RISK}$ is determined in partial and in total using Root mean square (RMS) approach. Partial risks represent the $T\&K_{RISK}$ in relation to the basic, core, and spearhead independently, whereas total risks indicate the $T\&K_{RISK}$ relating to the whole effect of the basic, core, and spearhead T&K.

The partial risk is calculated using following equations:

$$T\&K_{RISK\ BASIC} = \sqrt{\left((Sum\ of\ CV^2)_Q\right)^2 + ((Sum\ of\ CV^2)_C)^2 + ((Sum\ of\ CV^2)_T)^2 + ((Sum\ of\ CV^2)_F)^2} \quad (16)$$

$$T\&K_{RISK\ CORE} = \sqrt{\left((Sum\ of\ CV^2)_Q\right)^2 + ((Sum\ of\ CV^2)_C)^2 + ((Sum\ of\ CV^2)_T)^2 + ((Sum\ of\ CV^2)_F)^2} \quad (17)$$

$$T\&K_{RISK\ SPEARHEAD} = \sqrt{\left((Sum\ of\ CV^2)_Q\right)^2 + ((Sum\ of\ CV^2)_C)^2 + ((Sum\ of\ CV^2)_T)^2 + ((Sum\ of\ CV^2)_F)^2} \quad (18)$$

Where,

Q = All quality attributes
C = All cost attributes
T = All time attributes
F = All flexibility attributes

$$CV = Coefficient\ of\ variance = \frac{Standard\ deviation}{Mean} \quad (19)$$

$$Standard\ deviation\ (\sigma) = \sqrt{\frac{\sum(X-Mean)^2}{N}} \quad (20)$$

Where X is a set of number, N is number of sets.

The total risk is calculated using following equations:

$$T\&K_{RISK\ TOTAL} = \sqrt{(T\&K_{RISK\ BASIC})^2 + (T\&K_{RISK\ CORE})^2 + (T\&K_{RISK\ SPEARHEAD})^2} \quad (21)$$

Source of equations in step 6 is [12].

4 Results

The data of all six companies studied are analyzed using the same procedure as presented in the section "Methods of data analysis"; therefore, this section provides details on the results for Company A while the results for Company B, C, D, E, and F are presented in summary and comparison tables.

4.1. Company A

Figure 2 shows that the expectations established by company A for the attributes mostly surpass past experience. The highest difference between future expectations and previous experience is 3 (see attributes 3, 7, 8 and 19 in Figure 2), while the smallest difference is 0.5 (see attributes 11, 14, 15 and 18 in Figure 2). Furthermore, attributes 16 shows no gap between future expectations and prior experience. This signifies that company A's data and information privacy policy appears to be effective.

Figure 3 depicts the resource allocation of company A in the past. Attributes 3, 6, 7, 8, 10, 19, and 21 are discovered to be under-resourced, whereas attributes 2, 14, and 18 are found to be over-resourced. This suggests that company A has had the greatest difficulties with knowledge and technology management, as well as processes and workflows, while concentrating too heavily on the performance of research and development. The number of balanced attributes in the future is exactly the same as in the past, yet the attributes themselves are not entirely the same (see Figure 4). Company A appears to be pessimistic about their company's resource utilization in the coming years, particularly in the areas of knowledge and technology management, along with processes and workflows. Nonetheless, it is clear that approximately half of the attributes show an increase tendency in resource allocations.

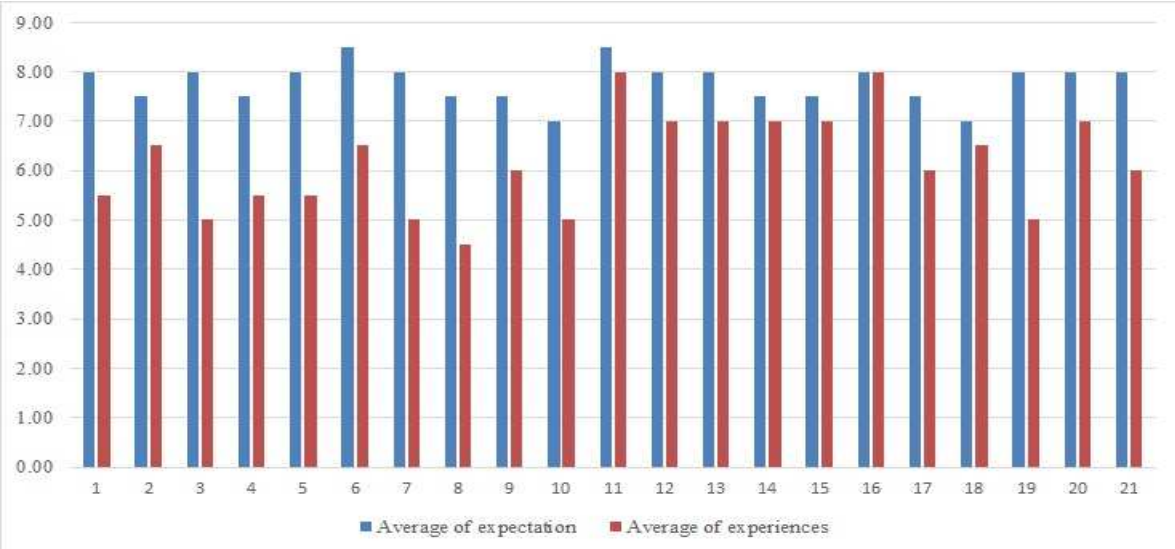

Figure 2 Average of Expectation vs Experience – Company A

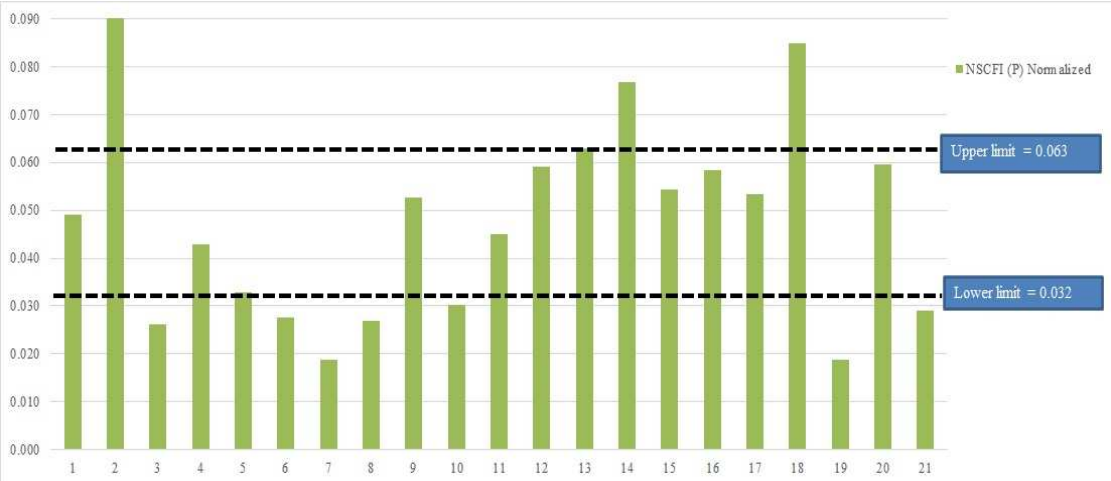

Figure 3 Resource allocation in the Past – Company A

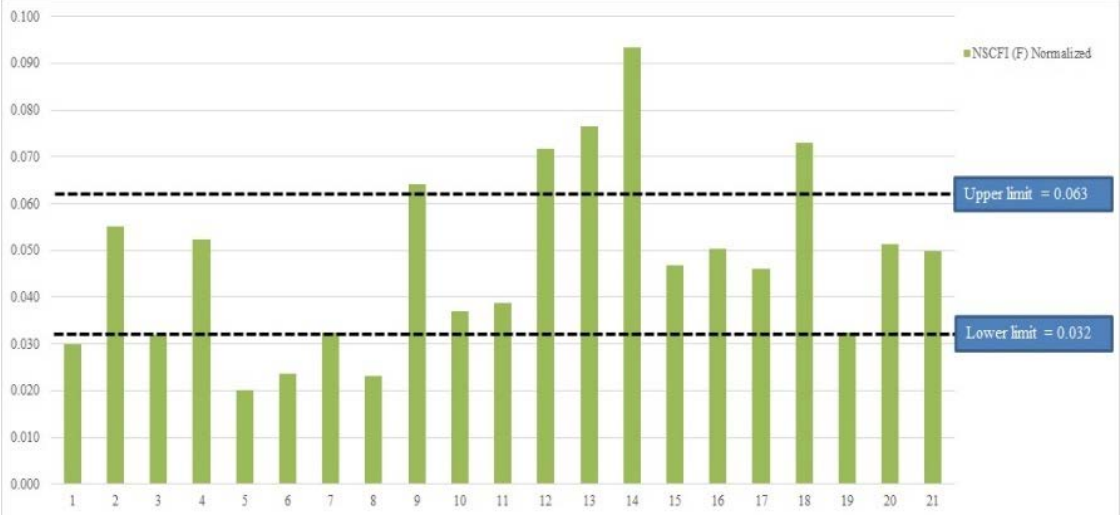

Figure 4 Resource allocation in the Future – Company A

Table 1 and Figure 5 show the MSI values for company A. The nearer the MSI value is to 1, the more accurately it describes the strategy type of the company [33]. Table 1 shows that the MSI values for Analyzer are high both in the past and in the future, with a value of 0.99. This shows that Company A's past business strategy was Analyzer, and that the strategy for the future is still Analyzer, but a bit more dominant.

Table 1 MSI result – Company A

	Prospector	Analyzer	Defender	Reactor
Past	0.90	0.99	0.91	0.90
Future	0.91	0.99	0.90	0.90

The SCA values calculated based on past scenarios are greater than those determined based on future scenarios, as shown in Table 2. This indicates that resource allocations provided appropriate support for Company A's operations strategy in the past while in the future operations strategy gets less support from resource allocation, possibly making it less sustainable.

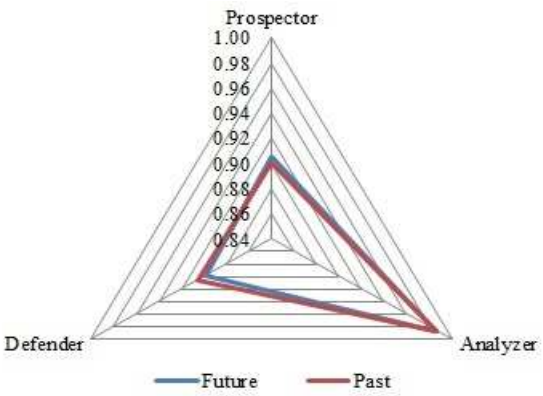

Figure 5 MSI triangle – Company A

Table 2 SCA result – Company A

	Measures of SCA risk level		
	MAPE	**RMSE**	**MAD**
Past	0.87	0.92	0.93
Future	0.80	0.88	0.91

In terms of technology and knowledge, Company A employs 31.74% basic T&K, 38.90% core T&K, and 29.36% spearhead T&K (see Figure 6). It can be concluded that company A prioritizes spearhead T&K the least while prioritizing core T&K the most.

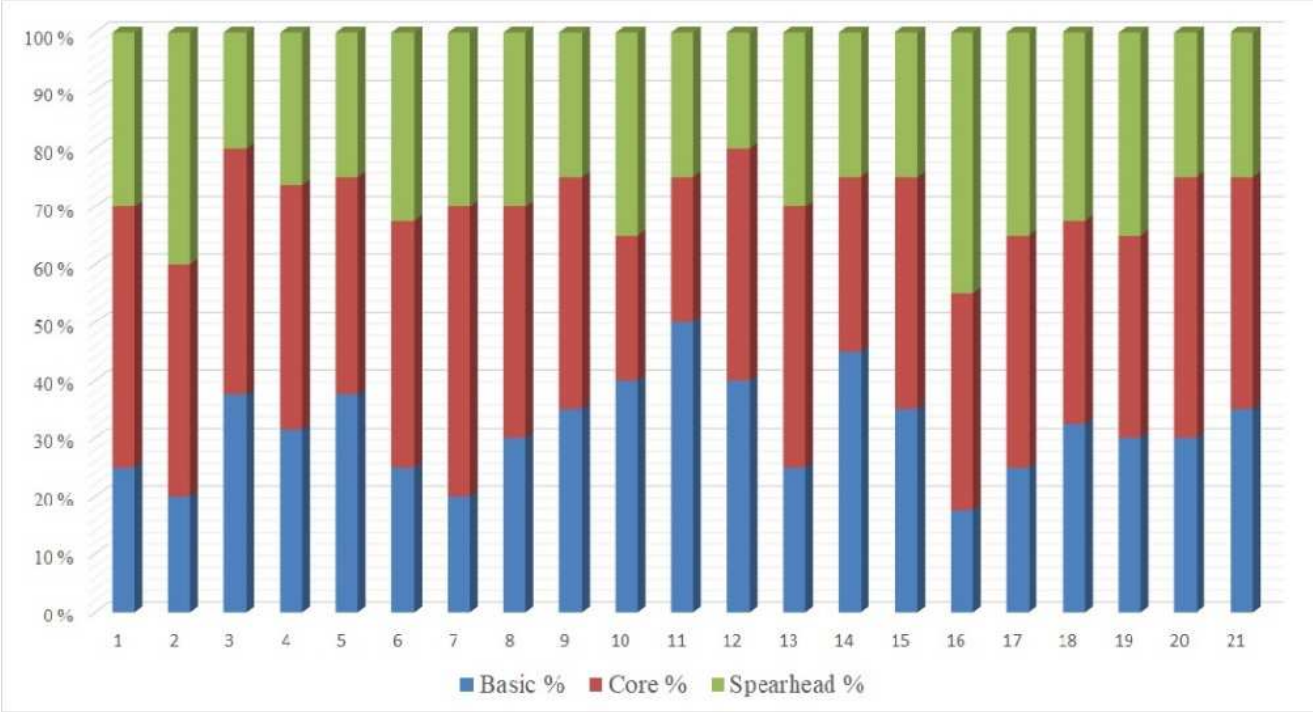

Figure 6 Ranking of Technology & Knowledge – Company A

T&K risks for basic, core, and spearhead are 1.743, 2.43, and 6.83, respectively (see Figure 7). Furthermore, total T&K risk is found to be 7.46 (see Figure 7). These risk values implies that spearhead T&K has the most risks, whereas basic T&K has the lowest risks.

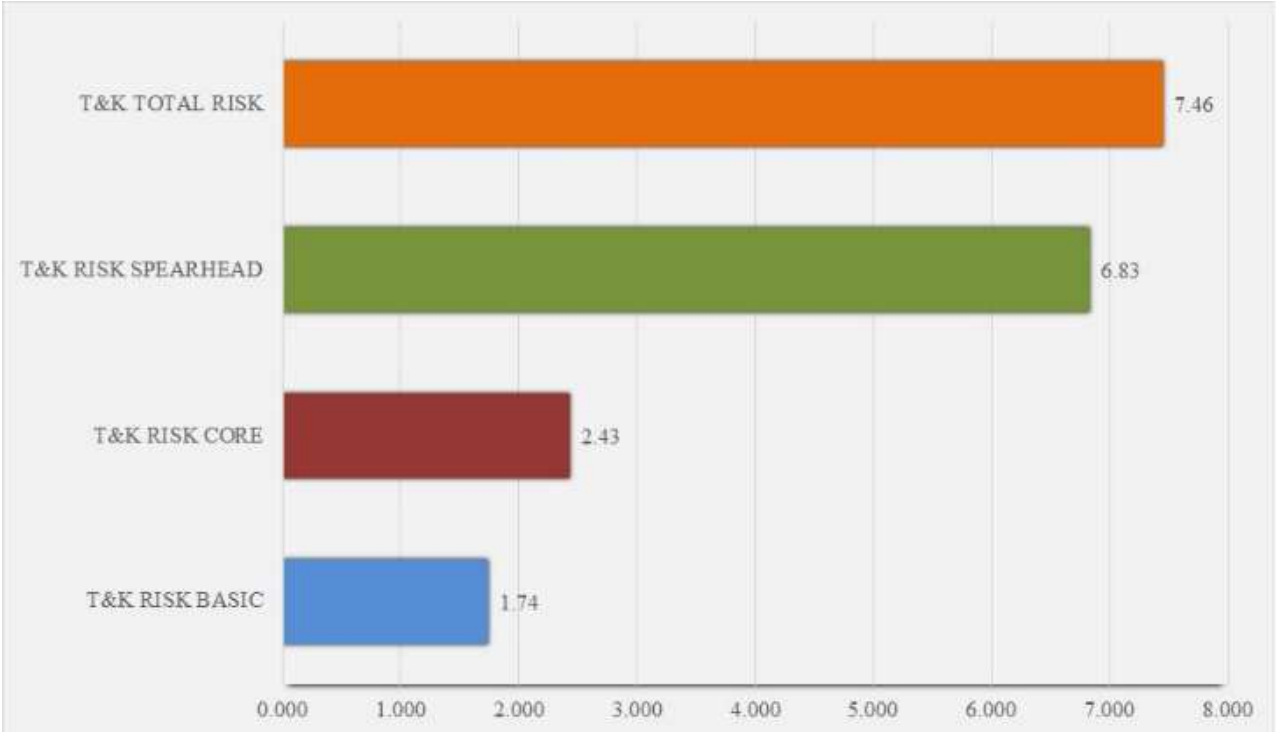

Figure 7 Technology & Knowledge risk – Company A

4.2. Company B, C, D, E, and F

Similarly to Company A, the expectations established by Company B, C, D, E, and F for the entire 21 attributes are higher than previous experience. In terms of the allocation of resources, it can be noticed from Table 3 that the number of balanced attributes for all five companies is greater than or equal to ten both in the past and in the future. Furthermore, it is shown that the number of balanced attributes tends to maintain or increase in the future, except for Company C with a slight decrease. These results demonstrate that respondents from these companies seem to be relatively positive about the usage of their companies' resources in the years to come. However, to strengthen any ineffective attributes that may currently exist, companies are required to develop a strategic plan wisely.

Table 3 is read as follows (example with Company B): Out of the 21 attributes (see Appendix 1), Company B has 5 under-resourced attributes, 10 balanced attributes, and 6 over-resourced attributes in the past. Other information in the Table 3 must be read in the same way.

For the MSI competitiveness, Table 4 points out that Analyzer results for all five companies was high in the past, ranging from 0.98 to 0.99, and will be high in the future, ranging from 0.96 to 0.99. This demonstrates that these five (B, C, D, E, and F) companies' business strategies have been Analyzer in the past and are expected to be Analyzer in the future, but with a slight decrease for company B.

Table 3 Resource allocation in the Past & Future – Company B, C, D, E, and F

		Under	Balance	Over
Company B	Past	5	10	6
	Future	3	17	1
Company C	Past	5	12	4
	Future	4	11	6
Company D	Past	3	14	4
	Future	4	14	3
Company E	Past	5	11	5
	Future	4	14	3
Company F	Past	3	15	3
	Future	1	18	2

Table 4 MSI competitiveness – Company B, C, D, E, and F

		Prospector	Analyzer	Defender	Reactor
Company B	Past	0.90	0.99	0.89	0.90
	Future	0.90	0.96	0.89	0.90
Company C	Past	0.91	0.98	0.91	0.91
	Future	0.91	0.99	0.90	0.91
Company D	Past	0.90	0.98	0.91	0.90
	Future	0.90	0.98	0.90	0.90
Company E	Past	0.90	0.98	0.89	0.90
	Future	0.90	0.98	0.90	0.90
Company F	Past	0.90	0.98	0.90	0.90
	Future	0.90	0.98	0.90	0.90

Regarding SCA values, Table 5 shows that over half of the values for Company B, C, and F are close to 0.9 and will increase slightly in the future. It means that the operations strategy of these companies was sustainable to some extent in the past but will become more sustainable in the coming years. The sustainability of Company D and E also follows an upward trend; however, the values found in the past are not very high. This indicates that in the past their companies' operations strategy might not have had adequate support from resource allocations.

Table 5 SCA results - Company B, C, D, E, and F

		MAPE	RMSE	MAD
Company B	Past	0.81	0.88	0.91
	Future	0.81	0.88	0.91
Company C	Past	0.83	0.90	0.92
	Future	0.86	0.91	0.93
Company D	Past	0.76	0.86	0.89
	Future	0.81	0.88	0.91
Company E	Past	0.77	0.86	0.89
	Future	0.79	0.87	0.90
Company F	Past	0.81	0.88	0.91
	Future	0.85	0.91	0.92

In terms of technology and knowledge categories, Table 6 indicates that Company B, D, and F give basic T&K the highest rank while giving the lowest priority to spearhead T&K. Company C also places the least weight on spearhead T&K, whereas it places the most value on core T&K. Company E, on the other hand, does not appear to prioritize one T&K above the others. This might indicate that, Company E should conduct more studies to see whether the allocation of such strategies impacts the competitiveness of the attributes.

As shown in Table 7, basic T&K has the lowest risks in Company B and D while core T&K has the lowest risks in Company C, E, and F. Spearhead T&K has the highest risks across all five companies.

Table 6 Ranking of Basic, Core, Spearhead Technology & Knowledge – Company B, C, D, E, and F

	% Basic	% Core	% Spearhead
Company B	49.52	29.05	21.43
Company C	39.05	42.62	18.33
Company D	41.90	38.57	19.52
Company E	33.10	33.21	33.69
Company F	40.95	40.00	19.05

Table 7 Technology & Knowledge risk – Company B, C, D, E, and F

	Basic	Core	Spearhead
Company B	0.24	1.01	1.52
Company C	0.93	0.32	1.05
Company D	2.52	2.53	4.31
Company E	1.40	1.13	3.83
Company F	2.39	1.85	4.18

5 Discussion and conclusion

The objective of this research is to assess the sustainable competitive edge of pharmaceutical SMEs in southern Vietnam on the basis of current orientation, direction of development, and sustainability of competetitive advantage. The present strategic priority of all six companies, according to the results, fits into Analyzer. As illustrated by Figure 8, although there is a difference in priority order, quality has been identified as the crucial element in the past and will continue to be so in the future, implying that quality is the primary source of competitive advantage for pharmaceutical SMEs in southern Vietnam. In a similar manner, among basic, core, and spearhead T&K, basic T&K is figured out to be the primary source of competitive advantage, and spearhead T&K is found to be the main source of risk in operations strategy and SCA (see Figure 9). In addition, it can be said that the direction of development of pharmaceutical SMEs in southern Vietnam is Analyzer because the MSI values for Analyzer reach the highest level. In other words, their strategic orientation in the future is toward quality, cost, and time (see Figure 5 and Table 4). This answers the research question 1.

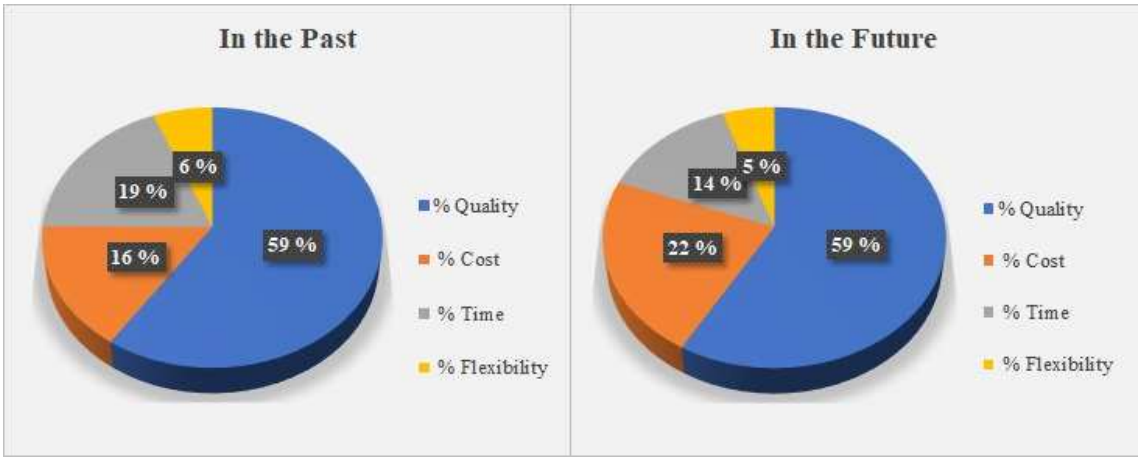

Figure 8 Percentage of Quality, Cost, Time, and Flexibility for all the 6 companies on average

The result is in accordance with the nature of pharmaceutical company, where product quality is always a top priority. Figure 8 also shows that, in the following years, cost will rise to second place, while time will fall to third place. Due to the Covid-19 pandemic, as well as the global energy crisis caused by the ongoing Russia-Ukraine war, Vietnam's pharmaceutical industry has been facing a number of challenges, including a broken supply chain, increased raw material and transportation costs, and changes in consumer habits and drug demand [7]. As a result, pharmaceutical companies have been attempting to cut costs and restructure operations and supply chains. However, the Covid-19 pandemic has also created a strong wave of innovation in the healthcare industry in general and the pharmaceutical industry in particular [7, 34], which has led to an increase in competition among enterprises in the industry. In light of this, pharmaceutical companies, especially small and medium-sized, tend to choose to be Analyzer in the upcoming years to adapt more easily to the new market development and also to maintain their position in the market. Since the studied companies favor a quality-cost-time (QCT) operating approach, they should aim to become more technologically adaptable in achieving higher satisfaction on on-time delivery and revenue target achievement.

In addition, most of the domestic pharmaceutical enterprises in Vietnam have previously focused on producing and trading popular drugs on the market with limited technology [11]. They also lack knowledge and high-quality human resources for product research and development. Therefore, the fact that enterprises aggressively race to innovate technology to gain market share will create enormous risks. Because of these matters, the companies should keep an eye on the risk levels connected with spearhead technology, as it was found to carry higher risk (see Figure 9).

From the NSCFI chart of resource allocations, it can be stated that in the past, more than half of six companies under-prioritized attribute 6 (Design and planning of processes and products), attribute 10 (Control and optimization of all types of inventories), and attribute 19 (Availability of information in information systems), while two attributes are over-prioritized, namely attribute 2 (Innovativeness and performance of research and development) and attribute 14 (Well-defined responsibilities and tasks for each operation). Regarding attributes that are over-prioritized and under-prioritized, the companies should think about balancing them according to their own points of view, internal business strategies, and market requirements. According to the trend, it is clear that respondents are confident about the future of their companies and that the companies' development path seems to be stable and is anticipated to stay the same or possibly get better.

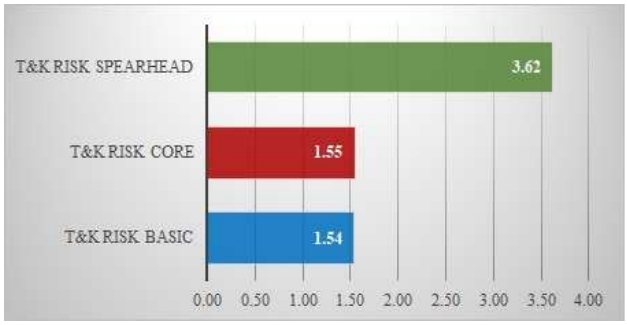

Figure 9 Technology & Knowledge risk for all the six companies on average

In terms of sustainale competitive advantage, all six enterprises agree that the MAD method, and maybe the RMSE method, outperform the MAPE method in identifying SCA risks. Nevertheless, if the MAPE method produces an index below 0.9, it could mean that there is a small inconsistency between the resources [2]. Furthermore, it should yet be tried with a larger number of businesses of various types and sizes to determine the optimal formula for validating the strategic decision (MAD, RMSE, or MAPE). Additionally, as seen from Table 5, over half of SCA values obtained using historical scenarios are close to 0.9 and will increase slightly in the

future. Hence, the operations strategy of pharmaceutical SMEs was sustainable to some extent in the previous years and will be slightly more sustainable in the coming years. This answers the research question 2.

Because the data was gathered from only two participants from each company, generalizing the results is problematic. However, one plus side is that, according to the respondents' own opinions, there is a strong correlation between MSI (Analyzer) and CFI (P). Regardless, the respondents are astonished by several of the unbalanced attributes. Another aspect worth emphasizing is that the descriptions of technology and knowledge questions were fairly hard for the respondents to fully comprehend; consequently, this may cause uncertainty in the results.

This research opens a new path for further studies. Some future research can be conducted by:

- increasing the size of the respondents as well as the companies participating in the study to increase the degree of reliability;
- comparing the results of the evaluation of sustainable competitive advantages using different methodologies;
- analyzing in-depth the impact of technology and knowledge on operations strategy or sustainable competitive advantages of either pharmaceutical SMEs or the pharmaceutical industry.

To sum up, this study demonstrates that research on sustainable competitive advantage is necessary for pharmaceutical SMEs as they could be regarded as a valuable resource for identifying the company's operational shortcomings and strengths and, as a result, taking the necessary actions to ensure the company's long-term success.

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Appendix 1. Sense and respond questionnaire

QUESTIONNAIRE: Sense and Response (S&R)

Please complete the following table considering 2 to 3 years' experience in the past and 2 to 3 years expectation for the future. The sum of Technology and knowledge share should be 100% i.e. basic + core + spearhead = 100%.

ATTRIBUTES	Expectations	Experiences	Trend (Future)			Trend (Past)			Compared to competitors			TK share		
			Worse	Same	Better	Worse	Same	Better	Worse	Same	Better	Basic	Core	Spear Head
	(1-10)	(1-10)												
Knowledge & Technology Management														
1. Training and development of the company's personnel														
2. Innovativeness and performance of research and development														
3. Communication between different departments and hierarchy levels														
4. Adaptation to knowledge and technology														
5. Knowledge and technology diffusion														
6. Design and planning of the processes and products														
Processes & Work flows														
7. Short and prompt lead-times in order-fulfilment process														
8. Reduction of unprofitable time in processes														
9. On-time deliveries to customer														
10. Control and optimization of all types of inventories														
11. Adaptiveness of changes in demands and in order backlog														
Organizational systems														
12. Leadership and management systems of the company														
13. Quality control of products, processes and operations														
14. Well defined responsibilities and tasks for each operation														
15. Utilizing different types of organizing systems (projects, teams, processes...)														
16. Code of conduct and security of data and information														
Information systems														
17. Information systems support the business processes														
18. Visibility of information in information systems														
19. Availability of information in information systems														
20. Quality & reliability of information in information systems														
21. Usability and functionality of information systems														

Appendix 2. MSI Questionnaire

MSI Questionnaire

Please evaluate the following criteria in every pairwise comparisons what are more important in your opinion. Please circle (O) the evaluation values for past and future situation considering 2-3 years in the past and future. Here, 1 means both the criteria are equally important and 9 means the criteria is extremely important over other.

Main criteria	Pairwise comparisons	Main criteria
Costs	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Quality
Costs	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Delivery
Costs	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Flexibility
Quality	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Delivery
Quality	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Flexibility
Delivery	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Flexibility

Table1: Pairwise comparison of four main criteria considering 2-3 years' experience in the past.

Main criteria	Pairwise comparisons	Main criteria
Costs	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Quality
Costs	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Delivery
Costs	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Flexibility
Quality	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Delivery
Quality	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Flexibility
Delivery	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Flexibility

Table2: Pairwise comparison of four main criteria considering 2-3 years in the future.

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