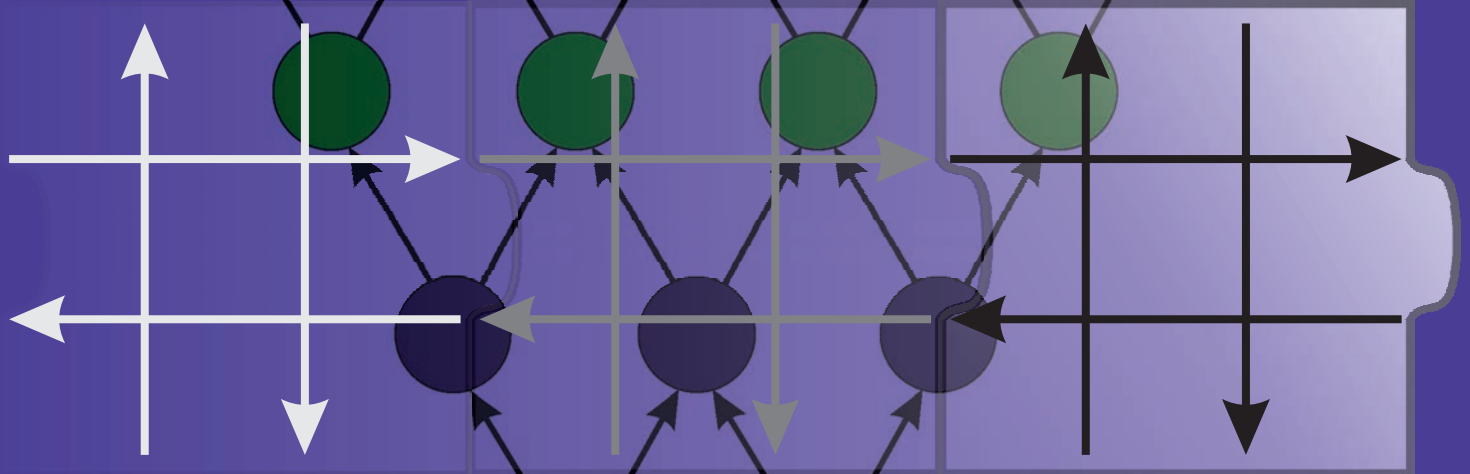
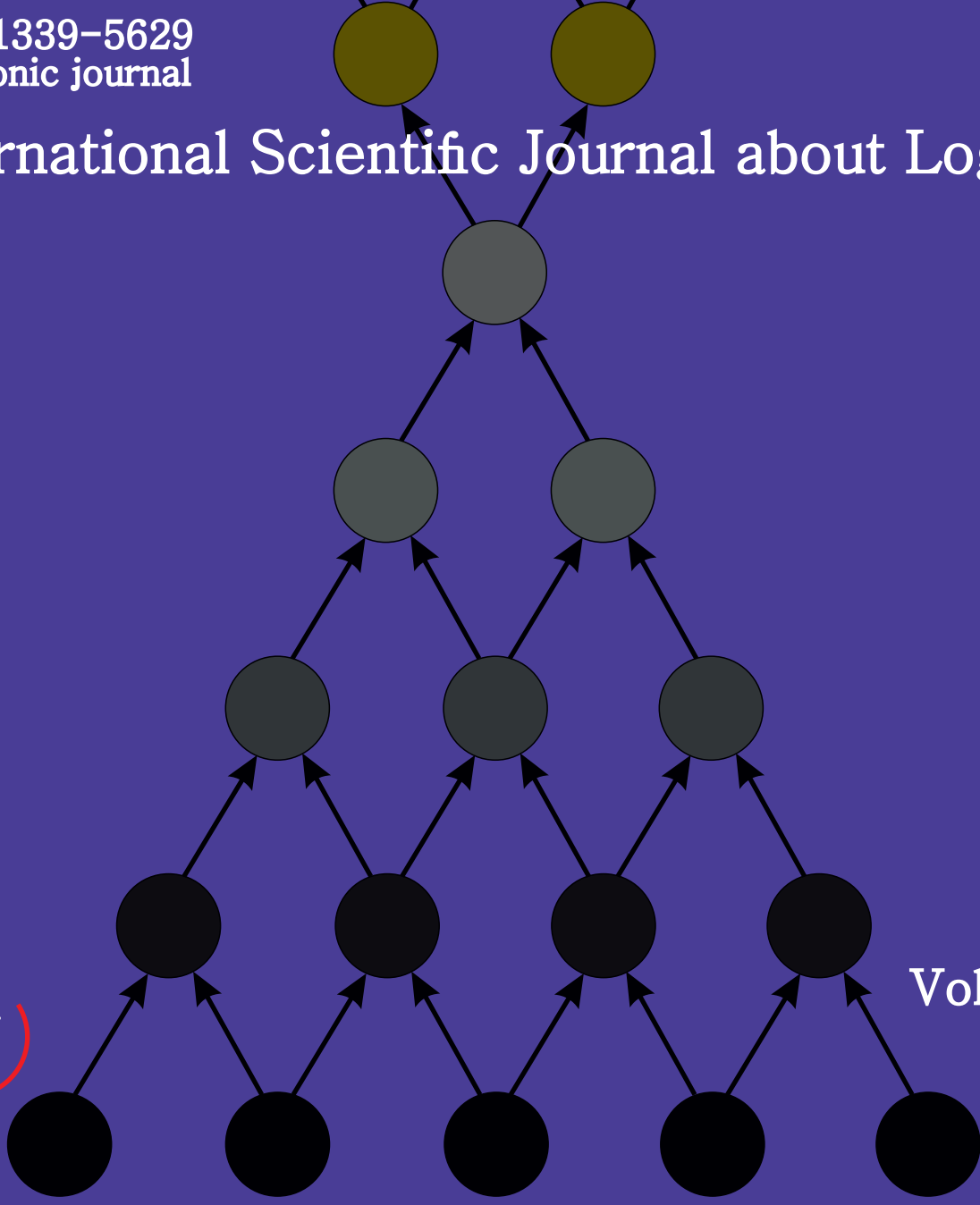


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Development of a hybrid artificial neural network method for evaluation of the sustainable construction projects

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Keywords: construction management, sustainability, materials, artificial neural network, construction projects.

Abstract: Planned methods may be developed to improve the efficiency of building construction. The construction business is profoundly impacted by the prevalence of inaccurate cost and schedule prediction. The main strategy to improve the project performance is to evaluate the hybrid sustainable materials using the artificial neural network (ANN) method based on the effective factors in construction projects in Iraq. This strategy needs an effective method to classify the project input representation and specify the accurate activity of each factor. This paper uses a hybrid artificial neural network to correlate and classify the sustainable hybrid of construction projects to evaluate their performance. The contribution of this method is the selection of the Multi-Criteria Decision-Maker method (MCDM) based on time and cost-effective factors correlated with the artificial neural network method. A dynamic selection procedure for project materials may be created using the existing technique as an evolutionary model for successful project completion. The MCDM observed that the appropriate sustainable material was considered as the main factor with a rank of 0.823 for cost effect and 0.735 for time effect and the main influence factor in Iraqi projects was the building height. The results present superior functional cost evaluation results correlated with the selection of hybrid sustainable materials.

1 Introduction

Effective project management ensures that both the needs of the client and the business are satisfied. A successful project accomplishes its goals while staying within its allotted budget and with minimal scope creep. The development of an appropriate model and methodology for cost estimating in construction projects is vital to the success of a project. Users who undertake their own cost estimating may find it difficult to put the results of current studies into reality due to the increased complexity of the cost estimation process [1]. Effective cost management is still the best approach to boosting construction sector efficiency and decreasing the number of abandoned projects and unhappy clients. However, there is still a challenge in determining the best approach to cost control. To rephrase, several elements contribute to the time and money needed for construction projects. The capacity to properly manage costs goes beyond simply keeping track of spending and producing cost reports. The ability to build with nearly flawless digital information and shifts in how businesses are conducted is driving a reaction to the construction industry's various cost control concerns [2]. The Theory of Industrial Evolution simplifies the process of making great decisions by highlighting the significance of four key factors: "Accuracy, Timeliness, Cost, and Completeness". In light of this, the construction sector is currently creating misleading and superfluous data [3]. Yet, the project's finances will decide its major turning points. In the absence of a predetermined budget, it is

difficult to determine whether or not the project is making satisfactory progress.

It is possible to estimate the quantity of certain needed components from the blueprints. Even if you have a good strategy in place, you do not need to rely on prior experience to make quantity estimates, provided the ultimate aim or job description is clear. An accurate estimate can only be obtained via the use of all-inclusive price estimating approaches, which in turn need more in-depth instructions and a substantial amount of work [4,5]. Due to the need of accuracy in managing costs, estimation is not always easy. A project manager's timeline has to take into account inflation, interest rates, fixed and variable costs, and overhead [6]. Parametric modelling and program assessment and review are two examples of the more mathematical methods used by certain academic institutions (PERT). You may either use a top-down or a bottom-up strategy. If you have access to price data from the past, the top-down method will work well for you. Decisions are best made by project managers who have worked on many comparable projects. For projects when there is a dearth of prior information, an organization may benefit from bottom-up techniques [7,8]. These approaches use task-specific cost estimates before aggregating them at the project level. Earned Value Management (EVM) is a cost-control method used in the field of project management. It offers an impartial assessment of the state of a project by combining the factors of time, money, and scope [9,10]. Specifications for a project are very in-depth descriptions of the project's tangible parameters.

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Everything from the overall square footage of a structure to its floorplate size, height, interior and external design, floor loadings, heating and lighting requirements, etc., is based on the building's intended use and anticipated occupancy rate. The total amount of money that will be spent on the structure may be divided into five groups: [11].

The specification describes in great detail the tangible features of the project. The quantity of paving material, the number of lanes, the number of bridges, and other elements are all taken into consideration while designing a road. In this regard, it might be useful to have a deeper understanding of the different materials used in the construction of buildings, homes, and other systems. Careful preparation is needed for the last stage of a building's life cycle, which is the processing of its materials. In the planning and creation of any building, the use of composites that are too difficult to deal with should be minimized as much as feasible [12]. Products that may be made from recycled materials without the need for any processing processes in between. Even though they are useless in their present condition, they can still be broken down into usable parts. To avoid downcycling and waste, they should be recycled without degradation in quality. Manufacturers should do more in terms of system integration, prefabrication, and even ongoing responsibility for the performance of their systems, some sources claim, because it is unrealistic to expect tradespeople to understand and properly install the numerous interconnected systems that make up larger commercial buildings [13].

A large toolbox and an array of methods are at the disposal of those in the building industry. In addition to the time spent working and the task itself, the output accomplished and productivity at the site may be determined via equipment and productivity control. As the overall cost of the project remains unaffected, the primary goal of control is to remove waste in usage. Twenty-five percent of Ugandans live in inadequate housing, but this number might be eliminated if the cost of building homes is reduced by 30 percent via industrialization [14].

Initial price estimates might be affected by factors such as a site's soil and drainage characteristics and access limits. Because of the poor ground conditions, extra manpower is required for excavation, piling, and foundational construction. Damage and breakage during handling, deterioration due to inadequate storage and poorly managed storage conditions, and short shelf life are all potential causes of product waste in storage [15]. Mismanagement, shoddy accounting, and an inability to account for all firm cash all contribute, as does the supervisor's cavalier attitude. Storage on the building site for an extended period of time accelerates the degradation. Requesting, ordering, receiving, inspecting, unloading, handling, storing, and distributing items are the phases when most material is lost [16].

In order to achieve sustainable development, it is necessary to carefully consider environmental implications throughout the design and execution of building projects. There has not been a lot of research into finding a happy medium between time, money, and ecological impact. Decision-making procedures have not been employed in project scheduling issues, despite the fact that using them is necessary when choosing an execution method for a project activity. In most cases, the length of time it takes to finish a project increases in proportion to the size of its budget. The schedule for completing a project depends heavily on the details of that project's design. As a rule of thumb, the time needed to complete a project is directly related to the scope of the task at hand. But this isn't always the case, and in many situations, if substantial additional resources are used, the project's implementation timeline can be accelerated [17].

Price inflation must be taken into account, and the longer it takes to complete construction, the more that inflation must be taken into account. When dealing with matters involving a government agency's financial projections, this is of the highest significance. For a project's final price tag to be accurate before construction starts, all expected expenditures must be accounted for [18].

Sixty percent or more of a building project's cost may be attributable to labour. Workers' contributions to a project's success may be split into "direct" and "indirect" categories. We compare the labour costs of major cities throughout the country. Compiling a list of pricing trends in chosen parts of the nation is necessary for the establishment of cities with economic conditions superior than the capital region [19]. There are flaws in the plans as well as the actual building. The lack of a quality control system and the use of untrained workers are to blame for the building defects. Corrosion and breaks in the reinforcing bars and uneven concrete settling are common problems with older constructions. Repairing and replacing damaged parts of a building is also more costly [20]. Factors affecting preliminary construction cost estimates were identified via a literature review [21]. To effectively manage a large project's budget—which might run into the hundreds of crores or millions of dollars—it is common to use state-of-the-art tools and techniques. Construction management's notoriously high resource requirements are a major roadblock to efficient resource allocation. The amount, quality, price, and availability of imported materials are all important considerations. There is a lack of data that analytically links particle shape and size as they pertain to gradation and the mechanical performance of materials. Substantial, and in some cases catastrophic, effects on the economy result from all of these causes [22].

Therefore, the evaluation of hybrid sustainable materials using artificial neural networks based on successful elements in Iraqi building projects is the primary way to enhance project performance. The project's input representation must be classified in an efficient manner,

and each factor's precise activity must be specified. In order to correlate and categorize the sustainable hybrid of building projects in this article, and to assess their performance, a hybrid artificial neural network is organized. This technique adds value by choosing the Multi-Criteria Decision Maker method based on variables that are both time and cost-efficient and are associated with the artificial neural network method. In order to provide a dynamic selection process for projects, the present approach is employed as an evolutionary project success model.

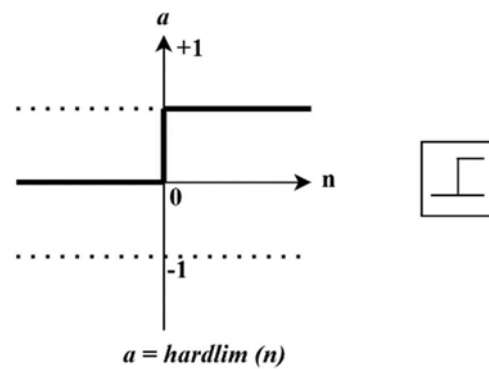
2 Methodology

The planned budget is the basis for all financial projections and assessments of the project's performance. The anticipated cost, however, must be evaluated to see whether it can be used to make a fair assessment of the project. This study's results provide an innovative approach to employing artificial neural networks to track the total cost of a project and its construction when hybrid sustainable materials are used (ANN). The approach, in this perspective, was created for the express purpose of monitoring the time and money invested in a certain project. The existing plan will keep tabs on the alterations made to the project for the different kinds of work being done. In order to put the ANN system to the test, we utilized the real building's walls as a test subject. In this investigation, we used a control mechanism to create budget deviations over time based on actual expenditures. The time and effort required to keep tabs on project costs as they are incurred will be reduced by using this technique. Actual expenses were compared to the budgeted targets on a regular basis. Goals may be established on a weekly, monthly, or yearly basis, depending on the scope of the project.

2.1 Artificial neural network technique behaviour

An ANN uses a multilayer perceptron application to find meaningful patterns in data rather than more standard statistical approaches like linear regression or bivariate correlation. Multilayer perceptron neurons are made to resemble their biological counterparts [23]. Because of its superior ability to capture both high levels of construction uncertainty and better accuracy, ANN is widely used in the industry. The ANN is maturing into a problem-solving modeller in the building industry. The construction sector has found success in using ANN to problems like as cost prediction, safety, productivity, and risk assessment. While an overview of this application is given, the specifics of how ANN may be used to the building sector are glossed over. Thereafter, the construction industry's future with ANNs is discussed in further detail. This article compares and contrasts ANN estimation and prediction, explores the robustness of ANN models, and considers whether or not they may be combined in a single framework [24]. The 'hardlim' transfer function is used in the perceptron neuron shown below. The sum of the weights assigned to each

external input ($w1j$) is then sent along to the hard-limit transfer function, which also gets an input of 1 from the bias. For illustration, consider the following example of a transfer function with a hard limit that only ever returns 0 or 1. Every perceptron neuron outputs a 1 if the net input into the transfer function is larger than zero and a 0 otherwise. In order for a perceptron to categorize input vectors, the hard-limit transfer function partitions the input space into two regions. If the net input n is less than zero, the output is zero, and if it is more than zero, the output is one [25].



Hard-Limit Transfer Function

Figure 1 ANN transfer function

Figure 1 depicts the input space of a two-input hard-limit neuron with weights $w1,1 = 1$, $w1,2 = 1$, and a bias $b = 1$. Classification space is cut in half by the decision boundary line L at $Wp + b = 0$. The bias b rotates this line such that it runs perpendicular to the weight matrix W . The hard-limit neuron will generate a 1 as an output if its input vector is located above and to the left of line L . When input vectors are below and to the right of the line L , the neuron produces a zero. The input space may be classified in a number of ways depending on the values of weight and bias you give it. Unbiased categorization lines will always begin at the point of genesis of hard-limit neurons. By including a bias, the neuron may handle input vector pairs that are not perpendicular to the origin. The accompanying diagram shows how this bias makes it possible to move the decision boundary further from the starting point. The `nnd4db` sample application may be run. You may change the position of a decision boundary, choose a different set of inputs to classify, and watch as the network learns to accurately categorize those inputs over and over again.

2.2 Many criteria decision making

By breaking down a complex problem into a multi-level hierarchical structure of objectives, criteria, sub-criteria, and alternatives, MCDM help to define the overall choice operation. Using this framework, a good next step can be chosen. Complex, unstructured, and multi-faceted judgments are perfect candidates for MCDM's application. These standards do not describe a linear set of options; rather, they take into account both physiological and

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psychological factors. The subjective assessment of the decision maker may be factored in and quantified using the Many Criteria Decision Making) framework [26]. The MCDM may be built with the help of the following three easy steps:

- 1) Determine the criteria weights by computing a vector.
- 2) Compiling a matrix of all conceivable score configurations.
- 3) Arrange the options in ascending order.

Every step henceforth will be elaborated upon for greater clarity. It's likely that the evaluation criteria will be looked at, and that n options will be graded. As an added bonus, a realistic approach to figuring out whether the findings can be believed will be covered. Simple steps for data collection are outlined for the user, who then inputs that information into the program to get the desired outcomes [27].

- Step 1: Define Potential Solutions.
- Step 2: To specify the parameters of the issue.
- Step 3: Rank the criteria in terms of importance.
- Step 4: Find out how the weights compare to one another.

The software tool will use the data to execute the mathematical calculation and give weights to the criteria depending on the data. A person may evaluate their alternatives and choose the one that best fits their needs once the appropriate weighted criteria have been entered into the appropriate places in the equation. [28]. Elewe et al [29] and Abdullah et al [30] presented a new algorithm to apply in solving the complex problems, they used Firefly algorithm and developed this algorithm with using a scanning method. Talib et al [31], Ali et al [32] and bin Hasnan et al [33] used MC-GPSO algorithm to develop a method to solve large scale problems. A very small portion

of the overall cost to build a family home out of wood is attributable to transportation [34]. The authors evaluated that legal standards affect the logistics of businesses in order to promote long-term sustainability [35].

3 Result and discussion

3.1 Many criteria decision making effective factors results

The construction industry has a poor track record of effectively predicting costs because key elements that affect costs are often disregarded or underestimated. To back up his claims, the author performed research on the Iraqi construction industry and found that the most influential factors include: Successful construction businesses are built on a solid foundation of reliable cost accounting. From Table 1, it was observed that the most influential factor in building time and cost was building heights. In addition, Table 2 exhibits that the used sustainable materials are not appropriate for the project design. The MCDM value varies between 0.823 and 0.735 for cost and time, respectively. As it was seen in Table 2, the geotechnical evaluation of the subsoil at the project site is necessary in order to supply useful input data for the design and construction of foundations for the planned buildings. Recording and collecting data on the project's costs and progress toward completion are crucial to cost management. Figure 2 exhibits the cost vs the number of floor data which also help the construction stakeholders to manage their budget for the project. The system provides an equation to exhibit the cost growth, which helps predict the project's overall cost with a single equation. Furthermore, it necessitates evaluating actual development against projected outcomes. Profit maximization within the allocated time limit while keeping the quality of the work to an acceptable level is the major goal of cost control for any given project.

Table 1 The influencing factors for this research

Influence factors on building cost and time	MCDM	MCDM
Number of floors in the building	0.60	0.65
Type of used walls material	0.63	0.64
Type of slabs	0.65	0.63
Walls materials quantities	0.59	0.57
Slabs materials quantities	0.58	0.55
Project area	0.65	0.66
Building height	0.70	0.70
Type of external plastering and warping	0.66	0.68
Type of tilling	0.63	0.68
Site position	0.68	0.54
Sites risks	0.66	0.57

Table 2 The management of sustainable materials

No	Factors	MCDM of cost	MCDM of time
F1	The used sustainable materials are available near the site	0.719	0.688
F2	The used sustainable materials are not appropriate for the project design	0.823	0.735
F3	The inventory in the work site is not suitable for used materials in the project	0.754	0.707
F4	The used sustainable materials cannot be cheated or replaced	0.723	0.642
F5	The contractor can efficiently deal with the required materials	0.763	0.676
F6	Often the contract is obligated to pay directly	0.792	0.722
F7	The payment is often obligated to purchase	0.775	0.664
F8	The works must be continues as planned for the event of non-payment	0.735	0.638
F9	Purchases are obligated to provide materials with the project even if delay in wage	0.806	0.726
F10	Failure to make payments does not affect the supply of raw materials	0.794	0.657

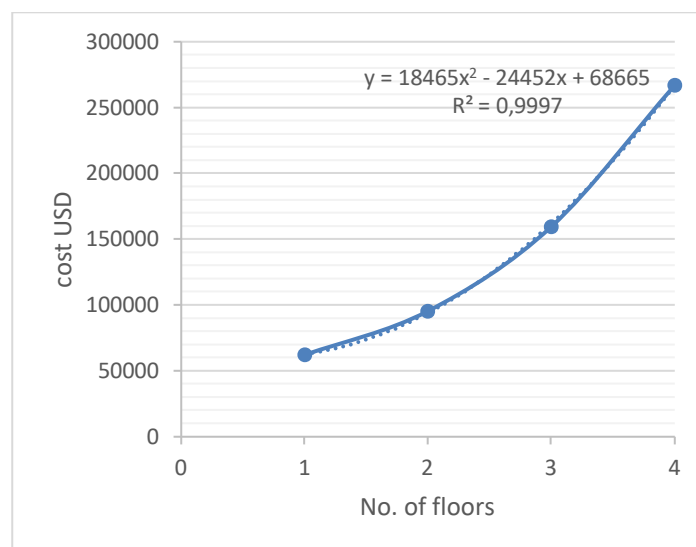


Figure 2 The cost growth in building construction

3.2 Artificial neural networks - ANN model results

A computer model that mimics the functions of human brain cells, an artificial neuron network (neural network). "Artificial neural networks" refer to computer systems that use "learning algorithms," or programs that can autonomously make modifications, or "learn," when given with new information (ANNs). This idea was crucial in providing the researcher with the information and computations needed for efficient management of both time and money. In order to achieve the same or comparable effects when applied to artificial intelligence, neural networks, a subset of computer architecture, pulls lessons from the functioning of organic nerve systems. The neural network may be thought of as a mathematical function that takes in a series of inputs and returns a series of outputs that the user specifies. Artificial neural networks' models are consistent with those of biological

neural networks. They have an exposed exterior layer, one or more concealed layers, and a concealed interior layer. Input data There is no information unique to the system that can be gathered from the transfer functions. Although they were originally designed for use with a certain kind of connection, they may be modified to work with any link type. The stacked neural network model used in the proposed prediction approach is trained and evaluated using three separate ANN models. The first version of the ANN model for structural analysis takes in four inputs and outputs two. Second, there must be a total of five inputs to the wall but only two outputs. The third model, which we'll call the foundation model, has two outputs and six inputs. Keep in mind that first-generation neural network-based price estimation algorithms suffered from a number of serious drawbacks. optimized performance with three different types of networks.

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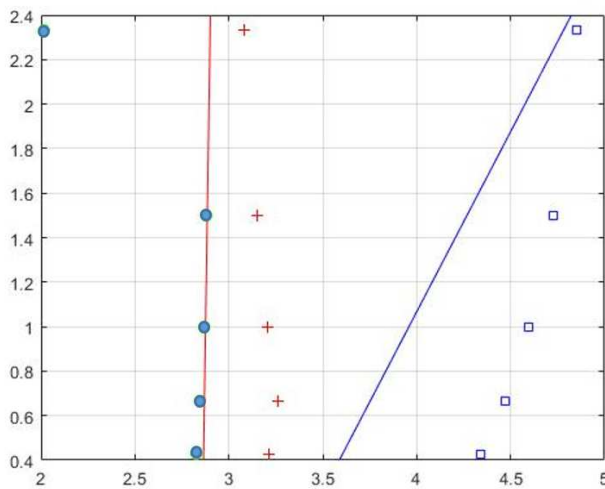


Figure 3 The ANN classification results

The current system was designed, built, and put into place to capture all data required for each project. A sample set of real-world inputs is collected from the data's rightful owner and organized for use as a model. The purpose of this stage is to assess the program's infrastructure and decide whether or not it can support a reliable method of data monitoring. Materials chosen for construction will be heavily influenced by the building code, which specifies the required levels of durability for various building components.

$$y = x^2 - 1.32x + 3.72 \quad (1)$$

If the right materials are used during construction, the building's functionality will improve. A three-story skyscraper in Baghdad, Iraq, was under dispute. We are concentrating our efforts on figuring out what happened to the old structure.

Table 3 The building cost results using the developed function

No of floors	Area	Cost USD
1	100	34,000
1	150	64,600
1	200	75,140
1	300	107,780
2	100	50,800
2	150	96,520
2	200	112,268
2	300	161,036
3	100	87,600
3	150	166,440
3	200	193,596
3	300	277,692
4	100	144,400
4	150	274,360
4	200	319,124
4	300	457,748

Cost model testing, as was previously said, is to determine whether the finalized model is effective and if the targeted degree of generality was achieved. By iterative development influenced by earlier advice, the ideal model was developed to provide more accurate cost projections with no loss of accuracy.

Table 4 The ANN hybrid material selection for sustainable building construction

No of floors	area	cost USD	ANN material results
1	100	34,000	BLOCK_THRMI STON
1	150	64,600	BRICK_BLOCK
1	200	75,140	BRICK_BLOCK
1	300	107,780	BRICK_BLOCK

By taking this approach, the model was able to generate more accurate cost projections without compromising accuracy. Better cost estimates could be made using this strategy. The results of the system's calculations are provided in the Tables 3 and Table 4 and the Figure 3, depending on the preexisting framework.

5 Conclusion

This research aimed to give a novel cost estimation method and selection of sustainable building projects in Iraq by developing a model employing sustainable materials. The main objectives of the present research are starting with finding the effective factor in building cost and time. The MCDM presented using appropriate sustainable materials for the project design as the main factor with a rank of 0.823 for cost effect and 0.735 for time effect. The second step is to investigate the main influence factor in Iraqi projects and the MCDM observed the building height as the main effective influence factor in the present work. Based on the presented results, the ANN trained to specify the suitable hybrid materials that can be used as suitable sustainable materials. the following steps and procedures were taken:

- a) A questionnaire survey, expert interviews, and an exploratory review of existing research were used to ascertain the cost-effective components of building projects. Most Common Differential Mean and the Mean for the Most Important Factors.
- b) There were a number of stages involved in creating an ANN model, the first of which was deciding on the program that would be used to construct the model. The flexibility of Microsoft Excel was a major factor in our decision to adopt it as our main cost estimating tool, along with its user-friendliness and capacity to extract data. Initially, the data sets were encoded before being analyzed.
- c) It is possible that the ANN method may provide accurate cost estimates for projects.

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Development of a hybrid artificial neural network method for evaluation of the sustainable construction projects

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Supplying aid products to affected regions by a natural phenomenon in Chiapas, Mexico

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Keywords: natural phenomena, supply network, Chiapas, vehicular routing problem.

Abstract: Natural phenomena affect differently in the world. It comes first from the geographical location, followed by the economic characteristics of each region. The objective of the case study presented is to design a supply network of essential products to victims in the state of Chiapas, located within the Mexican Republic, which is one of the states most affected by the appearance of natural phenomena. The vehicular routing problem with capacity is applied as a solution for the supply of aid products to 120 of 124 municipalities impacted by natural phenomena of a hydrometeorological type during the period 2015-2022. Evaluating the different municipalities that are home to the state under study through various Infrastructure and service factors, the municipality of Tuxtla Gutiérrez is determined as the origin of the routing, obtaining with it a total of 44 routes with an average of 2.7 municipalities to be supplied per route and an average of 402 km travelled. A second municipality is located, Tapachula, which obtains a second place in evaluating factors, providing the longest route in the distance travelled.

1 Introduction

Natural disasters are a serious threat worldwide. In the last 20 years, they have caused more than 1.2 million deaths and direct losses above 3.3 trillion dollars [1]. According to their origin, natural disasters are classified as meteorological and biological, with meteorological being hydrological or geophysical [2].

The appearance of natural phenomena and the degree of impact they have on human beings is not the same in all regions of the world. For example, we can mention Latin America and the Caribbean, the second most prone region to suffer disasters due to natural phenomena in the world. From 2000 to 2020, there were 1,205 disasters, including floods, hurricanes and storms, earthquakes, droughts, avalanches, fires, extreme temperatures, and volcanic events. Mexico is among the countries most affected by storms. Likewise, because it is located along the "ring of fire," it is exposed to volcanic activity [3]. In the same way, the degree of affectation of these phenomena is not the same; this is partly a consequence of the levels of economic development, which, among other factors, is reflected in the region's infrastructure.

There are various classifications of the disaster care phases; in general, they fall within one of the following moments: 1. before the disaster, 2. during the disaster, and

3. after the disaster. That is why it is worth mentioning that, through a great diversity of tasks and activities carried out at different times, humanitarian logistics is in charge of valuing, providing, storing, transporting, and distributing the personnel and services required in some areas affected by a disaster. It aims to provide emergency supplies to the affected areas quickly and on time, minimizing deaths and human suffering [4].

A helpful tool in the area of humanitarian logistics is the model of the Vehicle Routing Problem (VRP) in its different variants, which is used to design the routes that allow, among other things, the interest of this document, the delivery of products people affected by a natural disaster.

The *capacity vehicle routing problem (CVRP)* is the classic version of the vehicle routing problem (VRP). It is a problem where each vehicle has a known capacity, and loading it above said capacity is not permissible. Two aspects emerge from CVRP: *a) ACVRP* when the cost matrix is asymmetric, and *b) SCVRP* when the cost matrix is symmetric [5].

The formulation of integer linear programming of ACVRP proposed by [6] is presented through 1. Table 1 shows the assumptions, inputs, and outputs accompanying the formulation of the problem, and Table 2 shows the set of equations that form the mathematical formulation.

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Table 1 Assumptions, inputs, and outputs

	Description
Assumptions	The demand is deterministic.
	The demand is not split.
	The vehicles are similar.
	The vehicles are located in a central depot.
	Vehicle capacity restrictions are assigned.
Inputs	$G = (V, A)$: a complete graph.
	$V = \{0, \dots, N\}$: the vertices set.
	A : the arc set.
	D_j : the demand of each client ($D_0 = 0$).
	C_{ij} : the travel cost (from vertex i to vertex j).
	.
	SCV : set of client.
	$d(S) = \sum d_i$: the total demand of the set.
	K : the number of identical vehicles.
	C : the capacity of each vehicle.
Outputs	$X_{ij} = 1$ if the arch(i, j) $\in A$ if the arc belongs to the optimal solution and 0 otherwise.

$$\min \sum_{i \in V} \sum_{j \in V} C_{ij} X_{ij}$$

Subjects:

$$\sum_{j \in V} X_{ij} = 1 \quad \forall i \in V / \{0\} \quad (1)$$

$$\sum_{j \in V} X_{ij} = 1 \quad \forall i \in V / \{0\} \quad (2)$$

$$\sum_{i \in V} X_{i0} = K \quad (3)$$

$$\sum_{j \in V} X_{0j} = K \quad (4)$$

$$\sum_{i \in S} \sum_{j \in S} X_{ij} \geq r(S) \quad \forall S \subseteq V / \{0\}, S \neq \emptyset \quad (5)$$

$$X_{ij} = \{0,1\} \quad \forall i, j \in V$$

Equations (1) and (2) are input and output, respectively; equations (3) and (4) establish the deposit requirements; Equation (5) is the capacity constraint, which stipulates that each cut $(V/S, S)$ defined by a set of customers S is traversed by a number of arcs greater than $r(S)$.

Throughout the world, researchers have carried out studies based on the VRP, combining it with other techniques to provide solutions to the various variables that arise from the impact of natural phenomena. Among these, we can mention those presented in point 1.1.

The present investigation is made up in this introductory section with concepts and definitions in humanitarian logistics. Many studies were carried out by researchers from all over the world using the vehicular routing model. The problem arises in Chiapas, Mexico. The methodology shows the set of actions carried out to evaluate and give a solution to the problem of delivery of

products to victims of a natural event. Lastly, the results obtained through graphs and images are shown, and a comparison is made, allowing the discussion of the results and the conclusions.

1.1 Estate of the art

The interest in studying applications of the vehicular routing problem within humanitarian logistics is growing daily. In the article of [7], the authors present a literary review of the 2009-2019 period of the vehicle routing problem (VRP) applied to natural disasters in South America; the results of their research are a) most of the models They are deterministic, with VRP being the most widely used; b) Its application phase is mainly in the post-disaster phase; c) A large number of them seek to minimize time and operating costs, and d) For small scenarios, the most used models are the exact ones. Similarly, the work of [8] addresses the application of vehicle routing models to solve problems arising from the appearance of a natural phenomenon that causes a disaster. In this same area, it is worth mentioning that the application of the VRP brings with it the use of software that allows its resolution [9] in, which the authors make a comparison of the software used as VRP resolution tools, finding 6 with the best characteristics in terms of feasibility.

The planning phase is highly relevant within the administration of any process; in the case of product delivery, various researchers have worked on generating schedules that minimize the disaster's impact on victims. We can mention [10], where the authors use multi-objective evolutionary optimization with greedy heuristics to generate item distribution schedules under heterogeneous vehicles. It allowed them to generate an efficient alternative to find effective distribution schedules minimizing time and operating costs.

In the same way, various researchers have proposed mathematical models as a basis for decision-making in the disaster response process. Such is the case of [11], in which the authors propose a mathematical model for planning the use of helicopters for logistics activities in disaster response operations; with a feasible result in the methodology, the authors minimize the total time operation and mobilization of air resources. However, heuristic models should not be left behind as a logistics tool, allowing the problem of reasonable computational time. In the case of [12], the authors propose a mathematical optimization model and a heuristic based on a genetic algorithm to solve the problem of routing and programming humanitarian assistance.

Regarding the application of the VRP to specific cases, we can mention [13] who determine the number and location of shelters, collection routes for evacuation, and attention time for victims in the event of an earthquake, by modeling the problem. Location-routing with time windows (LRPTW) in the same way, a phenomenon that has caused significant problems in item distribution is the appearance of the Sars-Cov-2 virus, increasing the opening

of many supply centers to supply their products to remote areas. The researchers [14], based on modeling the routing problem for vehicles with capacity, redesigned the delivery routes of a store of social interest to their supply centers, decreasing about 24% the distance traveled by.

Continuing with the literary journey, it is worth mentioning the investigation of [15], the researchers applying the nearest neighbor (NN) heuristic technique and the capacity vehicle routing problem (CVRP), obtain and compare the delivery routes of necessities in the municipality of La Perla, Veracruz, Mexico. At the same time, the investigation of [16] evaluates a logistic model of the literature whose foundations are 1. The p-median problem for the location of a warehouse; 2. An extension of the model (qR) to calculate the products to be supplied, and 3. The problem of multiple vehicle routing with the capacity to deliver products to affected municipalities in Veracruz, Mexico.

Similarly, the research of [17] presents a new mathematical model for the Location Routing Problem with Private Fleets and Common Carriers (CLRPPC). The model can be adapted to solve the Vehicle Routing Problem with Private Fleets and Common carriers (VRPPC). And the Multi-Depot Vehicle Routing Problem with Private Fleet and Common Carrier (MDVRPPC). The models are validated with instances from the literature with satisfactory results. While the researchers [18] present a WEB application for the allocation of deposits and establishment of routes for the supply of distribution centers, considering population probabilities.

The paper in [19] presents a method to determine how to transport the maximum number of disaster victims to hospitals in metropolitan cities on time. The proposed method uses mathematical models, programming theory, heuristic methods, and the geometric Voronoi diagram. The goal is to transport the maximum number of patients on time, and the Voronoi diagram is used effectively to break down the complex problem. The article contains case studies of three hospitals in Tehran. Likewise, it is worth mentioning the work of [20], in which the researchers describe a study whose objective is to statistically evaluate the effects of various design factors on the performance of the casualty transport system in large-scale disasters. The authors propose a data-based decision support tool to improve casualty survival and ambulance transport times during the disaster response phase.

Continuing with the investigation of establishing transport routes in the event of a disaster, it is worth mentioning the investigation of [21], which has in its context the worst flood that occurred in Kelantan in 2014. The researchers evaluate and identify locations for shelters and routes relief. The simulation is performed using HEC-RAS and ArcGIS to map the best possible locations and modes of transportation for disaster relief. Likewise, the

research of [22] proposes a mixed integer programming model and a two-stage hybrid metaheuristic method to solve the post-disaster humanitarian logistics problem. The model considers the medical assistance team and the distribution of relief supplies between the different demand points. The model is tested on problems of different sizes and a numerical example based on the 2016 Kyushu, Japan earthquake. Finally, the research of [23] addresses the importance of effectively managing relief supply operations and routing vehicles for delivery to help natural disaster victims.

1.2 Problem statement

Mexico is especially vulnerable to natural disasters. It is because its territory is located between the faults of the North American plate and the Cocos plate, which brings with it highly seismic regions. Likewise, it is surrounded by the Pacific Ocean and the Atlantic Ocean, thus having impacts from hydrometeorological phenomena. In addition to the above, critical human settlements are located in geographical areas with seismic activity or can suffer the impact of hurricanes of many categories [24].

The Chiapas state is in the southeast of Mexico, bordered to the north by Tabasco, to the west by Veracruz and Oaxaca states, to the south by the Pacific Ocean, and to the east by the Republic of Guatemala. It has a territorial area of 74,415 km²; it occupies 3.8% of the national territory, making it the eighth largest state, with a population of 5,543,828. Chiapas ranks 8th at the national level for its number of inhabitants [25]. Figure 1 presents the geographic location of Chiapas within the national territory (a) and its municipal division, with 124 municipalities comprising it (b).

Chiapas is one of the six states of Mexico with the most significant number of affectations by hydrometeorological phenomena; 120 of 124 municipalities suffered one or more effects during 2015-2022. For example, in 2022, Hurricane Stan's passage affected more than 670 homes in the municipality of Escuintla [27]. It is worth mentioning that of its 124 municipalities, of which: 1 is classified with a lesser degree of marginalization; 7 municipalities have a low degree of marginalization; 29 municipalities have a medium degree of marginalization; 67 municipalities have a high degree of marginalization, and 20 municipalities with a very high degree of marginalization [28].

Therefore, the present case study aims to design a delivery network of essential products to areas affected by a natural phenomenon in Chiapas under the assumptions of 1. The roads are not damaged; 2. Considerable traffic; 3. Pertinent climatic conditions; 4. No social problems in terms of demonstrations and security, and 5. Qualified driver. For which the methodology embodied in the continuous section is established.

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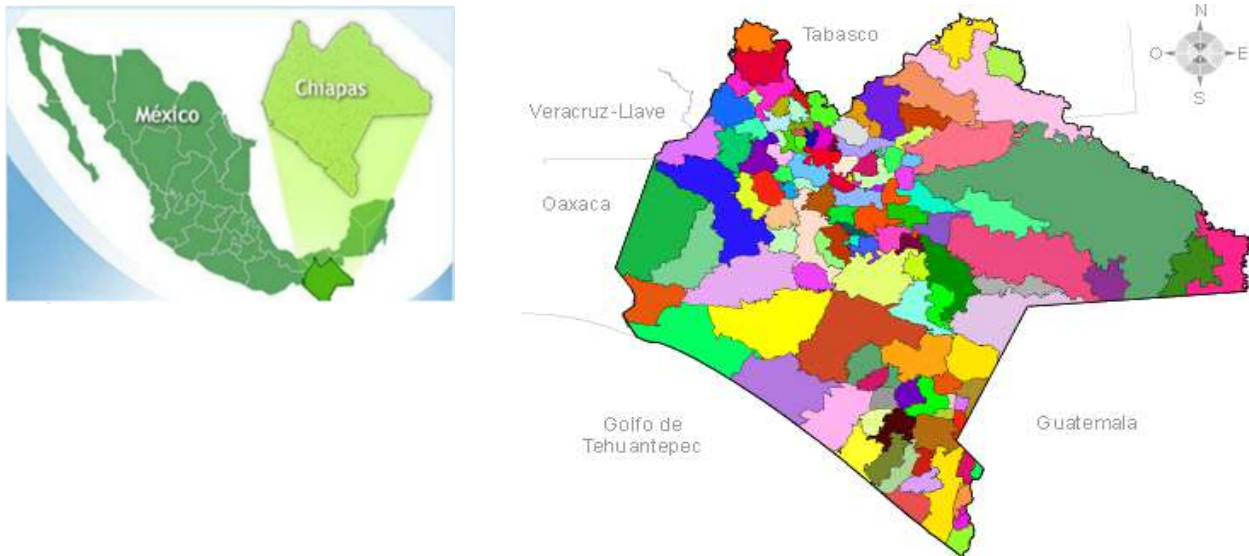


Figure 1 Location and municipal division of the state of Chiapas [25,26]

2 Methodology

The methodology to solve the problem of supplying necessities to areas affected by some natural phenomenon in the state of Chiapas is shown in Figure 2. It is divided into three stages (1) Collection of information from the municipalities that make up Chiapas: *a)* Municipalities that make up the state; *b)* road access, essential services, social interest stores, and degree of marginalization of each municipality; *c)* municipalities impacted by natural phenomena during the period 2015-2022 and a number of victims; *d)* necessities of the area, price and dimensions; *e)* product integration device for delivery, with content for families of four people, and *f)* means of transport for delivery and dimensions of their containers. (2)

Development of databases for the supply of the CVRP programming *a)* database of the characterization and evaluation of each of the municipalities that make up the state of Chiapas in order to select the one with the highest weighting for locating a point of origin of routes; *b)* municipalities impacted by some natural phenomenon during the period 2015-2022, integrating the number of victims in each one; *c)* matrix of distances between the point of origin and impacted municipalities; *d)* Calculation of container capacity of the delivery vehicle; *e)* feeding the programming into Lingo 19®, and *f)* running the program. (3) Presentation of results *a)* generation of tables with the routes obtained, showing the municipalities to be supplied on each route, the distances traveled, and the groceries supplied; and *b)* comparison between venues.

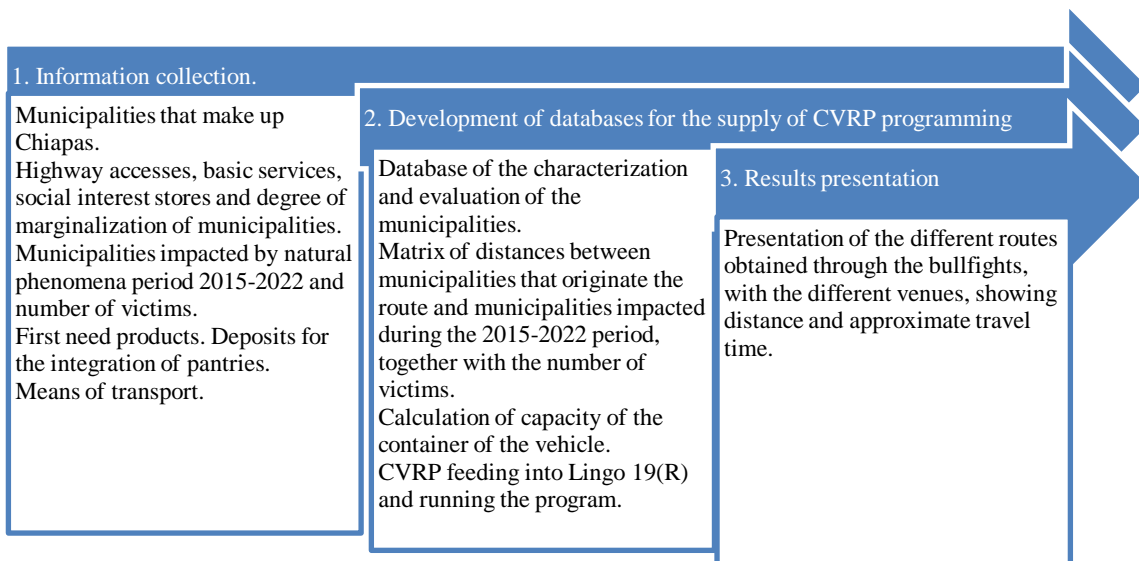


Figure 2 Problem-solving methodology

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2.1 Information collection

This first step is based on seeking and collecting transparent information that allows the generation of tools to feed the CVRP programming.

2.1.1 Municipalities that make up the state of Chiapas

The state of Chiapas is made up of 15 regions; I. Metropolitan; II. Zoque Valleys; III. Mezcalapa; IV. From the Plains; V. Altos Tsotsil-Tseltal; SAW. Friary; VII. Of The Woods; VIII. North; IX. Isthmus-Coast; X. Soconusco; XI. Sierra Mariscal; XII. Lacandon jungle; XIII. Mayan; XIV. Tulijá Tseltal Chol, and XV. Comiteca Tojolabal Plateau. Which house a different number of municipalities, adding 124 in total. Such information limits the investigation's geographic scope [25,26].

2.1.2 Highway accesses, essential services, social interest stores, and the degree of marginalization of the municipalities

The information about types of road access, essential services, social interest stores, and the degree of marginalization of each of the municipalities will allow for establishing a geographical area. Where a pantry distribution center could be established, that is, a point of origin for people affected by the impact of a natural phenomenon, the information is obtained through databases of CONAPO (National Population Council) and the national report of INEGI (National Institute of Statistics and Geography) [26, 29].

2.1.3 Municipalities impacted by natural phenomena period 2015-2022 and a number of victims

The municipalities impacted by a natural phenomenon of hydrometeorological type during the period 2015 - 2022 are extracted from databases of the Natural Fund for Disaster (FONDEN), the National Center for Disaster Prevention (CENAPRED), and the National Civil

Protection System (SINAPROC) of the state of Chiapas Likewise, the calculation of victims is made from the average supply during the study period [30, 31].

2.1.4 Aid products

The content of the pantries is based on the AGREEMENT that establishes the Program's guidelines for the Attention of Emergencies due to Natural Hazards by the Secretary of the Interior (SEGOB), DOF 08/16/21, in the Transitory section. It establishes the Type B maintenance pantry for the southeast region [32]. These pantries are projected for four people (an average family).

2.1.5 Deposits for the integration of aid kits

For the deposits containing the set of products, a box of 40 cm long x 30 cm long and 30 cm wide is determined.

2.1.6 Means of transport for delivery and dimensions of the boxes

The means of delivery to consider is a 4-axle cargo truck, 8-ton tail type, with dimensions in the box of 943 cm long, 300 cm high, and 248 cm wide. It is used by social interest companies in territorial areas such as those present in the state under study [33].

2.2 Development of databases for the establishment of the CVRP programming

In this stage, the instruments that will allow the evaluation of the municipalities are generated.

2.2.1 Database of the characterization and evaluation of the municipalities

Table 2 shows an example of information organized according to the characterization of the municipalities and the region to which they belong (XIII. Mayan Region). Evaluating each region and its municipalities, the Tuxtla Gutiérrez city council has the highest compliance to be a point of origin in distributing food pantries to victims, followed by Tapachula.

Table 2 Mayan region characterization

Municipalities	Marginalization index	Degree of marginalization	Road access	Electric power	Sewer system	Telephony	Internet	Social interest stores
Catazajá	52.130	High	Federal & State	97.8	94.0%	14.7%	8.5%	0
La Libertad	52.693	Medium	Federal	98.3	96.2%	10.2%	9.4%	0
Palenque	52.674	Medium	Federal & State	98	92.9%	5.8%	16.6%	1
Benemérito de las Américas	51.419	High	Federal	97.3	91.3%	1.9%	6.5%	1
Marqués de Comillas	49.087	High	State	98.6	85.5%	1.9%	3.6%	0

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2.2.2 Matrix of distances between municipalities classified as the origin and impacted municipalities during the period 2015-2022

Two matrices are developed, one belonging to the municipality of Tuxtla Gutiérrez, as the point of origin, the impacted municipalities, and the number of victims converted into families of four. Moreover, another is a sensitivity test with the municipality of Tapachula, the second municipality with the highest compliance in characteristics to be a point of origin.

2.2.3 Vehicle box

Based on the dimensions of the product container and the vehicle box, a maximum capacity of 1840 pantries to be transported is established.

2.2.4 Feeding CVRP into Lingo 19

With the matrices as a power source and a total capacity of 1,840 pantries, the programming run is carried out in Lingo 19®

3 Results

As a distribution point, the municipality of Tuxtla Gutiérrez contains 44 different routes with an average of 3

municipalities to be supplied on each route, without a municipality being supplied through two different routes and an average of 402 kilometers traveled per delivery. In the same area, if the result obtained when the supply point is the municipality of Tapachula, there are 44 different routes, with an average of 3 municipalities to be supplied within each of them and an average route of 769 kilometers per route.

Table 3 presents some examples of the routes obtained through the CVRP program, having the municipality of Tuxtla Gutiérrez as the point of origin; as can be seen, the first route delivers to two municipalities and returns to the origin, with a total of 1,810 pantries supplied and 413 km traveled. The second route delivers to a single municipality, covers 30 km, and delivers 1,622 groceries. The Figures are obtained through the Google Maps® software.

Table 4 presents some examples of the routes obtained through the CVRP program, having the municipality of Tapachula as the point of origin; as can be seen, the first route delivers to a municipality and returns to the origin, with a total of 1,753 pantries supplied and 492 km traveled. The second route delivers to two municipalities, covers 93 km, and delivers 1,597 groceries. Figures are obtained through the Google Maps® software.

Table 3 Route with origin Tuxtla Gutierrez

ROUTE 1.		ROUTE 2.	
Tuxtla Gutiérrez, Berriozábal, Mapastepec y Tuxtla Gutiérrez		Tuxtla Gutiérrez, Chiapa de corzo y Tuxtla Gutiérrez	
Traveled distance	Families of victims	Traveled distance	Families of victims
Tuxtla Gutiérrez – Berriozábal = 26 km Berriozábal – Mapastepec = 137 km Mapastepec - Tuxtla Gutiérrez = 413 km Total = 413 km	Berriozábal=904 Mapastepec=906 Total = 1,810	Tuxtla Gutiérrez - Chiapa de Corzo = 15 km Chiapa de Corzo - Tuxtla Gutiérrez = 30 km Total = 30 km	Chiapa de Corzo =1,622 Total = 1,622

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Table 4 Route originating in the municipality of Tapachula

ROUTE 17		ROUTE 21	
Tapachula – Arriaga – Tapachula		Tapachula – Cacahoatán – Unión Juárez – Tapachula	
Traveled distance	Families of victims	Traveled distance	Families of victims
Tapachula – Arriaga = 246 km Arriaga – Tapachula = 492 km Total = 492 km	Arriaga = 1,753 Total = 1,753	Tapachula – Cacahoatán = 22 km Cacahoatán - Unión Juárez = 47 km Unión Juárez – Tapachula = 93 km Total = 93 km	Cacahoatán = 761 Unión Juárez = 836 Total = 1,597

4 Discussion

Although the results show that the number of trips traveled for the delivery of products is the same for both host municipalities, 44 routes, the average distance traveled for these varies considerably by approximately 47.72%. The municipality of Tuxtla Gutiérrez has a better geographical location, which allows a shorter mileage for the delivery of products with an average of 402 km, which would help reduce delivery and maintenance costs, and the municipality of Tapachula, with an average distance traveled of 769 km which implies a longer transfer time affecting the victims in a non-timely supply, both with an average supply of 3 municipalities per trip.

Likewise, within the characterization of the municipalities, Tuxtla Gutiérrez, being the capital of the state, occupies the best percentage within factors such as degree of marginalization, electric power, drainage, telephony, internet, hosted social interest stores, and road access, which facilitates the management of a warehouse. These two municipalities can be visualized in Figure 3; in green is the municipality of Tuxtla Gutiérrez, and in blue is the municipality of Tapachula, located in the south of the State bordering Guatemala.

Through a literary investigation, a case study of [34] is found where the problem of the location of facilities in the state of Chiapas is reflected, using the p-median, the researchers present as headquarters municipalities: Altamirano, El Parral, La Independencia, and Larráinzar under different scenarios, with an average of 609 kilometers traveled per route,

Although the results of this case study are satisfactory, some elements were not considered, such as breakdowns

or road closures, weather conditions, demonstrations, support personnel, and others that may arise from the impact of a phenomenon natural.



Figure 3 Municipalities of origin in routing

As mentioned, few studies are related to vehicle routing in Chiapas State, one with the highest frequency of impact from natural phenomena. In addition, it is one of the three states with the highest percentage of population poverty [35]; it is imperative to carry out studies that provide tools to the actors in the face of the disaster in the various phases that converge to it, to provide a solution or maintain a quality of life for the victims. Humanitarian logistics is becoming increasingly relevant to climate problems, and political and social problems have alerted numerous researchers who, through different methodologies, techniques, and methods, provide a solution to the

consequences caused. In this case, the CVRP was used to propose a timely supply.

5 Conclusions and future studies

It is known that logistics processes present a high cost to organizations, whatever they are. In the case of the actors before the disaster, the time factor is of predominant interest since it can be the difference between a person's life and death. Within emergency operations, items are distributed to victims, which is relevant to maintaining a quality of life. Chiapas is one of the states of Mexico which has suffered the impact of natural phenomena over time. Precisely, hydrometeorological type. The work aims to develop a delivery network for essential products to victims of a natural phenomenon. It is achieved through the characterization of municipalities to establish a geographical point which is the origin of the network. Then we look for the determination of the number of pantries to transport derived from the vehicle's capacity. Finally, the feeding of capacity and distance to the programming of the problem of vehicular routing with capacity. Obtaining as results: number of routes, municipalities that make up the routes, kilometers traveled on each route, and groceries to be transported.

Through the evaluation of the different municipalities that are home to the state under study through various infrastructure and service factors, the municipality of Tuxtla Gutiérrez is determined as the origin of the network, with a total of 44 routes and an average of 2.7 municipalities at supply for each one, through an average of 402 km traveled. A second municipality, Tapachula, is located, providing a longer route than in the case of Tuxtla Gutiérrez.

This study is essential for the actors who support society in a disaster context and for the community and researchers. Remember that a disaster can bring disastrous consequences not only at the time of the disaster but can trigger a series of effects for society, such as unemployment and economic instability beyond the affected area. This work provides a strategy for providing humanitarian aid as soon as possible. In addition, a real case study is used, facilitating the understanding of mathematical methods and stimulating critical thinking and creativity.

The CVRP provides an adequate solution to the product delivery area; as a suggestion in future works, the division of the network in more than one point of origin is planned, taking into consideration and weighting factor the frequency of impact to the municipalities to discard these as a network source.

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Categorization of urban logistics stakeholders

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Keywords: stakeholders, categorization, decision graph, urban logistics.

Abstract: The main challenge for urban logistics is to shift towards a system, working under the guidance of a competent authority working in collaboration with all the stakeholders involved, whether near or far. The ultimate goal of this coordination is to optimize resources and durations while maximizing benefits in a sustainable urban context. The choice of the route to be preferred is to be justified at the level of this article. This is the purpose of this document, which aims to prioritize the most important players in the field of goods transport at the urban level to highlight the areas of action. In this article, we recall several notions by providing several definitions related to the actors of urban logistics, including last-mile delivery and standardized categorizations. We then propose our own classification based on a questionnaire, which provides the necessary data for the development of three decision-making graphs based on the results of our analysis. By highlighting the most important stakeholders in urban logistics, we hope to provide a framework for more efficient and sustainable urban goods transport in the future.

1 Introduction

Due to the growing importance of e-commerce business, with an average growth of 10% per year (Melacini et al., 2018), as well as the current trend of urbanization where 47% of the global world population lives in urban environments (Elmqvist, 2018), new urban logistics concepts are required to guarantee favourable living and working conditions for urban actors. City dwellers are increasingly demanding a sophisticated transport infrastructure and traffic flows.

By 2050, the world population is expected to reach 9.7 billion, with over 66% living in urban areas (Revision of World Urbanization Prospects, 2018). Transportation, security, production, and distribution have been affected by this rapid urbanization and more lasting and recurring events related to climate change; the urban population depends on the efficiency of the logistics system. The efficiency of the logistics system is crucial for the urban population; discussions on these topics primarily focus on specific stakeholders such as residents, governments, carriers, consignees, transportation companies, and others.

Given the complexity of the logistics system, various stakeholders are involved, each with a unique role to play

in ensuring the smooth flow of goods from the point of origin to the point of consumption. The involvement of these stakeholders is vital in ensuring the efficient and sustainable functioning of the urban logistics system. By this integration, urban logistics can be optimized to meet the needs of all parties. It enables the development of logistics strategies that are responsive to the changing needs of the population, minimizes the negative impacts of logistics activities on the environment and reduces traffic congestion. It fosters collaboration and coordination among different stakeholders, which is crucial in ensuring the smooth functioning of the logistics system.

Stakeholders can be classified into several categories based on their level of interest and involvement in a project or decision-making process. By categorizing, it becomes easier to identify who needs to be prioritized and which stakeholders require more attention and communication throughout the decision-making process.

2 Methodology

2.1 Literature review

Although there has been a lot of research on sustainability in urban systems, most of it has focused on

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the three main axes of environment, society, and economy, with very little attention given to the infrastructural conditions associated with urban freight operations. There have been some interesting ideas, models, and frameworks proposed by various authors in the literature. Taniguchi (2014) provided an overview of city logistics, Olsson et al. (2019) reviewed the literature on last-mile logistics, and Boysen et al. (2020) surveyed last-mile delivery approaches from an operations research perspective. There has been research on consumer choice models for electronic purchases. Gatta et al. (2020) used an agent-based approach with discrete choice to investigate the possible acceptance of e-grocery, while Comi and Nuzzolo (2016) developed models to simulate purchasing decisions based on demographic and socio-economic factors. Van Duin et al. (2016) predicted delivery results based on historical delivery data from a logistics parcel service provider, while Russo and Comi (2020) analyzed end-user choices and found that socioeconomic characteristics and store location affect the quantity.

The literature on urban freight transport has identified five interest groups/stakeholders with different areas of interest in relation to urban delivery, including public bodies, associations and intermediate bodies, representatives from the private sector, residents or visitors, and other stakeholders (supporting units, manufacturers of delivery vehicles, educational institutions, research institutes and consultants, politicians and Members of Parliament, and local and public media of communication). This information was derived from the work of Zuccotti & Konstantinopoulou (2010), Russo & Comi (2010), Lepori et al. (2010), McLeod et al. (2011), and Iwan (2013):

- Public bodies: municipal administration, legislative and municipal executive authorities, authorities of neighbouring cities, regional authorities, and provincial and state authorities;
- Associations and intermediate bodies: chambers of commerce and business associations and organizations;
- Representatives from the private sector: carriers, forwarders, business and service unit owners;
- residents or visitors;
- other stakeholders: supporting units, manufacturers of delivery vehicles, educational institutions, research institutes and consultants, politicians and Members of Parliament and media of communication, local and public.

2.2 Last-mile delivery

Definition of "City"

Although the literature has shown increasing interest in city logistics related to last-mile delivery in the e-commerce market, most publications tend to focus on specific issues, such as the analysis of e-trade's impact on last-mile delivery (Allen et al., 2018) or end-user choices (Russo and Comi, 2020).

A city is a problematic and decentralized object that encompasses a multitude of socio-technical processes and networks, as well as hybrid groups and alternative typologies (Farías and Bender, 2010; Gutzmer, 2015). Modern cities are complex systems whose vigilance depends on the efficient working of municipal administration and management units, which encircle all essential areas. Cities are, among subjects, places of work, housing, recreation, shopping, and culture. Cities should allow the implementation and infrastructures of living requirements for residents and other users (internal or external visitors for each probable purpose), providing them with necessary living conditions, not necessarily ideal ones.

Sustainable last-mile

In the E-commerce market, Last-mile delivery is one of the many areas of urban freight transport (UFT) and can be defined as "a set of activities and processes involved in the delivery process from the last point of transit to the last delivery point in the supply chain (Yuen et al., 2018)".

The sustainability of urban transport has been discussed in the literature by Taniguchi et al. (2016), who proposed using big data and decision support systems for urban logistics. Customer value in last-mile delivery was discussed by Vakulenko et al. (2018), and the concept of crowdsourcing logistics was explored by Castillo et al. (2018). Location-routing problems with simultaneous home delivery and customer pick-up were discussed by Zhou et al. (2016), while Perboli et al. (2018) proposed a dual framework for simulation optimisation to evaluate environmental and operational settings for freight transportation. In spite of the several measures taken in cities, these are often unsuccessful. One of the main reasons for this situation is the lack of cooperation between the stakeholders (Gatta & Marcucci, 2016). In particular, stakeholders are sometimes excluded from the decision-making process that directly affects them (Macharis & Kin, 2017).

Among these needs, the requirements for efficacious mobility and accessibility to a large number of consumer goods and resources are of particular importance (Witkowski & Kiba-Janiak, 2014; Macharis et al., 2012). Achieving sustainability is a real challenge because it is only possible through the sociotechnical passage by introducing technological innovations in a complex social system (Geels et al., 2017; Canitez, 2019). Some researchers have developed an approach to designing and evaluating last-mile deliveries from the perspective of various stakeholders (Harrington et al., 2016).

To address local transport problems and ensure sustainable-efficient urban mobility, stakeholders in urban freight transport must work together collaboratively to develop sustainable plans. Unfortunately, city authorities currently lack tools to facilitate such integration.

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2.3 Stakeholders' classification

Stakeholders' definition

Urban innovation is a prime example of the involvement of multiple stakeholders in the development and implementation of complex innovations (e.g., Murdoch, 2000; Nilssen, 2018); Identifying specific barriers to innovation is crucial as it can help mitigate stakeholder opposition and resistance to change (Yu et al., 2019).

the urban environment is characterized by multimodal networks, disparate transport modes and conflicting interests of stakeholders, making last-mile deliveries a complicated system with many actors involving a wide range of entities in simultaneous interaction and related activities like operating and planning. In line with the complexity associated with city logistics, simulation is a widely accepted and commonly used solution that provides tools, approaches, frameworks and models in order to organize distribution activities and support decision-making processes (Crainic et al., 2018). Prior to commencing analysis, it is important to define the term "stakeholders". It refers to parties who are affected by a decision made without necessarily participating in the decision-making process. While some stakeholders are directly involved in urban transportation, such as component suppliers, manufacturers, carriers, retailers, and consumers, many others are not, such as city authorities, residents, and tourists/visitors (De Oliveira et al., 2016).

Classification of stakeholders

Effective management of urban logistics requires identifying and prioritizing the stakeholders involved in the process. There is a lack of research on stakeholders' classification in urban logistics. Without this, it becomes difficult to understand the complex network of interactions between them, their interests, and their influence on the decision-making process. This can lead to mismanagement of resources and result in inefficient and unsustainable urban logistics. There is a need to develop a comprehensive framework for the classification of stakeholders in urban logistics, which can provide a systematic and structured approach to understanding the relationships between stakeholders and their impact on the urban logistics system. Such a framework can help identify key stakeholders, determine their roles, and prioritize their needs, leading to better decision-making, improved collaboration, and more sustainable urban logistics.

Current situation and stakeholders' classification

The City logistics situation is an intricate structure where many actors with diverse (and usually contradictory) objectives and various types of delivery operations coexist alongside different and restrictive regulations governing access to city centers. It is seen from three viewpoints, which are represented by different stakeholders: from the demand side, supply and their physical surroundings controlled by governmental authorities (Bandeira et al.,

2018). Urban distribution confronts many hardships due to infrastructure congestion, external costs or conflicting interests between stakeholders' goals. UFT includes private companies (producers, carriers, retailers), final consumers working or living in urban areas, and public authorities (Karakikes and Nathanail, 2019). Taniguchi (2014) identifies three primary stakeholders involved in last-mile city logistics, namely freight transporters, municipal authorities, and the city's residents. According to Stathopoulos et al. (2012), stakeholders are viewed as entities with a vested interest in decisions concerning urban transportation matters within the broader understanding of the concept of urban logistics, Vakulenko et al. (2018). Though, the stakeholders can be divided into two groups as described in table 1:

Table 1 Public and private classification of stakeholders

Public	Private
Public transport operators – Authorities Residents City users – Traffic participants	Freight carriers - Senders Other private companies

Justification of the causes of stakeholders' conflicts

The successful implementation of urban innovations requires overcoming stakeholder opposition, as it can result in lasting actors' commitment and endorsement of goals (Williams et al., 2019; Hertel et al., 2019), which, in turn, increases their willingness to adopt urban innovations. It is important to reduce stakeholders' resistance by means of a structured innovation process. That can be reduced through a structured innovation process, as individual and organizational interactions in the ecosystem can create additional sources of resistance (Emani, 2018).

The diverse needs and interests of the aforementioned groups primarily stem from their divergent goals, which influence their operations and give rise to various conflicts (Rubini & Lucia, 2018; Russo & Comi, 2010).

- Public authorities aim to minimize the negative impact of transportation, creating an appealing city for residents and tourists.
- Private companies seek to deliver goods efficiently and cost-effectively, meeting the demands of end customers within shorter delivery times.
- City residents prioritize safety and unrestricted mobility within the urban environment.

Generally, the aim of this paper is to propose a plan for resolving conflicts of interest by prioritizing stakeholders in order to know who among them holds more power, efficiency and ability to act. This will help from a point of view firstly to understand who should act first and in what field he can intervene secondly.

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3 Result and discussion

Before starting our analytical study, we start by giving the definitions of essential stakeholders as shown in table 2:

Table 2 Definition of stakeholders

Actors	Definitions	Interests
Sender	An organization, operating under its own name, responsible for the transportation of goods on behalf of a client, either through direct transportation or by subcontracting the task.	Customer satisfaction Business satisfaction Reduction of costs & delays
Logistic provider	A company that offers assistance in managing the movement and storage of logistics operations.	Dispatching of deliveries Consolidation of freight with the same destination
Reversed logistics operator	An operator responsible for overseeing the retrieval, collection, repair, destruction, and assignments of products.	Customer satisfaction Quick and efficient pickup
Warehouseman	An operator tasked with the management of goods, including storage, rotation, movement, and organization.	Optimal stock level Good stock rotation
Local authority	Group of people with the authority to govern a state or a country. We will use the government instead of local authorities, because in Morocco power is held by this actor.	Ensuring a good quality of life for citizens Ensuring the safety of people Ensure the protection of the environment Maintenance of infrastructure
Cargo carrier	A company that is entrusted with the transportation of freight (goods) from one place to another, following a specific transportation scheme based on the characteristics of the infrastructure.	Safety of transported goods Fast delivery to the customer Cost reduction
Industrial	Production of goods.	Fast delivery to the customer Reduced transport costs Condensed deadlines
Driver	An intermediary between customers and manufacturers who facilitates the transportation process by coordinating the delivery vehicle.	Safety of goods and people transported
Resident	An individual who resides within a specific urban area.	Living in an unpolluted environment Security
Regulator	An agent responsible for ensuring efficient management of the transportation of goods, vehicles, and passengers.	Travel optimization Reduction of energy consumed
Dealer	An administrative body that provides approvals for transportation.	Safety of goods and people
Planner	Resource and needs match manager, transport and production planner.	Route optimization
Operations officer	Intermediate between the driver and the consumer utilizing all available human and material resources.	Good progress of transport operations
Customer	The recipient of the product, who may or may not be the ultimate consumer.	Reduced acquisition prices
Consumer	The final consumer who will utilize the product.	Advantageous rates

3.1 Attributes-based classification

After reviewing the opinions of various authors on the stakeholders of urban logistics, methods of analysis, specification, and categorization, it is necessary to examine the stakeholders as actors who regulate the entire chain by

influencing one another. The expectations of stakeholders, both public and private institutions, and the innovative objectives of urban transport are constantly in confluence, and their interactions must be considered.

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It is important to identify and characterize their distinct features. The more a characteristic is present, the more significant role an actor plays in urban logistics. We will define a set of characteristics that will be associated with

each stakeholder, which we will refer to as "attributes." These attributes may or may not be applicable to a given actor. Table 3 contains all the attributes and their legal lexicon's definitions:

Table 3 Attributes' definitions

Number	Attributes	Definitions
1	Opposition	It is the total refusal of one structure towards another or any manifestation of volition through which a person intends to stop the execution of a legal or judicial process. It can be presented by a physical or moral entity.
2	Acceptance	It is the fact that a person declaring that he subscribes to the undertaking offer which is proposed to him: it constitutes the apparent mark of consent. Acceptance can be express or implied.
3	Power	It designates the legal capacity to do one thing, to act for another for which one has received a mandate. It refers to the forms of authority within a state, such as the three powers: legislative, executive, and judicial. The public powers are the constituted authorities
4	Infrastructure	Set of works constituting the foundation and the installation on the ground of a construction or of a set of installations (for example roads, railroads, airports).
5	Public liability	It is incurred either because of the non-performance of a contract, or because of a voluntary act or not, involving for the person who is at fault or who is legally presumed at fault, the obligation to repair the damage. that has been suffered by one or more others.
6	Means of transport	In urban distribution, it is the intra-city public transport that is specific to a city or an urban environment, adapted to this environment. These must be of good quality and must meet some requirements.
7	Commitment	It is the act by which a public body creates or establishes against it an obligation which will result in a charge.
8	Conduct and behaviour	Characterizes all the reactions adopted by a person, in his environment and in the face of given situations. Here, the behavior acts on the distribution frequency.
9	Training and awareness	It is a program through which a group of people learning to work in the field of urban logistics is introduced to the risks, strategies and policies of its proper functioning.
10	Competence	In civil procedure, it is called « jurisdiction » which refers to the ability recognized by the rules of law for a court to hear a dispute. This can also mean the in-depth knowledge in a branch or field.
11	Moral responsibility	Moral responsibility is the need for a person to answer for his intentions and actions before his conscience. Obligation made to a person to answer for his acts because of the role, the loads which he must assume and to support all the consequences thereof.
12	Triggering	Induce by means of a mechanism the setting in motion of a mechanism or a process. Usually, the entity with more power is able to do so.
13	Leverage	It is an influence that refers to the fact that a physical or moral person uses their power and authority with the aim of abusing their influence, real or supposed, so that they can make a favourable decision.

The stakeholders-attribute matrix is actually a first selection of the most important actors of the urban logistics community. This sorting is necessary to reduce the number of parts to be processed. Once done, we will apply in a second step another differentiation of the remaining actors in order to prioritize stakeholders. In other words, once we get a long list of stakeholders, we need to categorize them. Some of them may have the power to block one decision

or advance another. Some may be more or less interested in the contribution or consequences of the project.

It is in this sense that the Power-Interest matrix comes into play with the intention of segregating/prioritizing the stakeholders. By drawing up this grid (Table 4). It becomes simple and efficient to identify the most important stakeholders based on their power and interest in the urban context.

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Table 4 Attributes' table

Stakeholders	ATTRIBUTES												
	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13
Sender	1	1	0	0	1	1	1	1	1	0	1	0	0
Logistic provider	0	0	0	0	1	1	0	1	1	1	1	0	0
Reversed logistics operator	0	0	0	0	1	1	0	1	1	1	1	0	0
Warehouseman	0	0	0	0	1	0	0	1	0	1	1	0	0
Government	1	1	1	1	1	0	1	0	1	1	1	0	1
Cargo Carrier	0	0	0	0	1	1	1	1	0	0	1	0	0
Industrial	0	0	0	0	1	1	1	1	1	1	1	0	0
Driver	1	1	0	0	1	0	1	1	0	0	1	0	0
Resident	1	1	0	1	1	0	0	1	0	0	1	1	0
Regulator	0	0	1	0	1	0	1	1	0	1	1	1	0
Dealer	1	1	0	0	1	0	1	0	0	0	1	0	0

3.2 Application of the Power - Interest grid on the selected actors

From the first selection of stakeholders -based on attributes- we have identified the most important. We note that for each appreciation, we associate a value interval with two steps and a half, as shown in Table 5:

Table 5 Appreciations' values

Values	Interest's appreciations	Power's appreciations
[0 - 2.5]	Not interested at all	No power

[2.5 - 5]	Little interested	Little power
[5 - 7.5]	Interested	Moderate power
[7.5 - 10]	Highly interested	Too much power

In order to present this matrix, we draw a summary table of the actors kept according to the number of points (attributes). We defined a margin of appreciation which allows to quantify the values of the powers and interest according to table 6. Below is a summary of these actors (Figure 1):

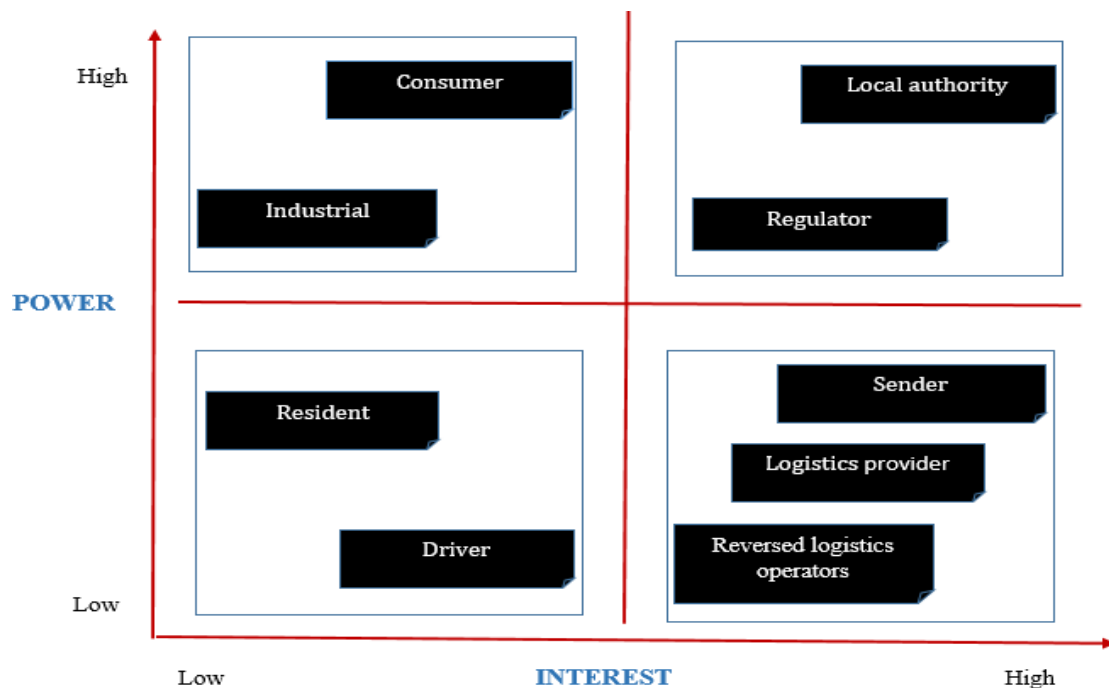


Figure 1 Alimented Interest – Power matrix

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Table 6 Retained stakeholders

Stakeholders	N° Points/Attributes	Margin of interest	Margin of power
Government	10	[7.5 - 10]	[7.5 - 10]
Consumer	8	[2.5 - 5]	[7.5 - 10]
Sender	8	[7.5 - 10]	[0 - 2.5]
Industrial	7	[5 - 7.5]	[5 - 7.5]
Resident	7	[0 - 2.5]	[2.5 - 5]
Regulator	7	[0 - 2.5]	[5 - 7.5]
Logistic Provider	6	[5 - 7.5]	[0 - 2.5]
Reverse Logistics Operator	6	[5 - 7.5]	[0 - 2.5]
Driver	6	[2.5 - 5]	[0 - 2.5]

3.3 Decision-making based on 3 elements Interest, Power & Efficiency

In the following section we will justify the values attributed to the interests and powers of the stakeholders. We are going to propose a questionnaire to collect tangible digital data.

The methodology used is composed of 5 distinct phases:

Phase 1 Reorganization of stakeholders

In the preceding analysis, we categorized stakeholders based on their importance without considering their roles in the value chain. For our next analysis, we will divide stakeholders into two groups based on whether they operate within the value chain or play a facilitating role. Figure 2 displays this distribution.

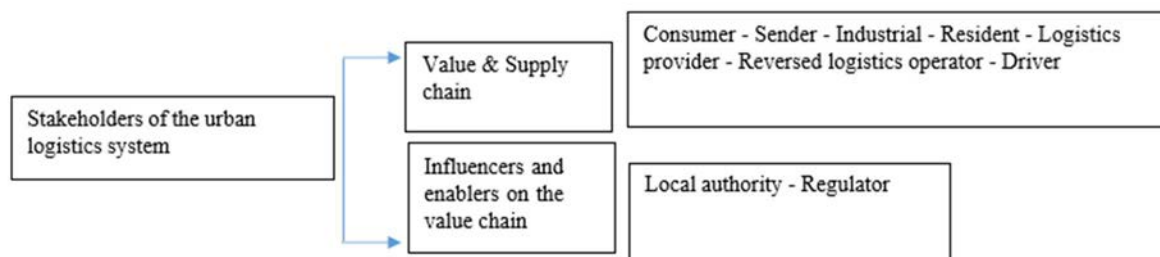


Figure 2 Positioning urban logistics stakeholders in the supply chain

Phase 2 Data gathering

To obtain more realistic data, we created a questionnaire and sent it to various urban logistics entities. Out of 27 recipients, 20 individuals who operate in this field completed the questionnaire. Unfortunately, we were unable to distribute the questionnaire to government entities, which we refer to as public authorities in our analysis. The questionnaire consisted of rating each stakeholder group's power and interest on a scale of 0-3:

- 0: No power / no interest
- 1: Low power / low interest
- 2: Average power / average interest
- 3: Strong power / strong interest

Question 1: What influence can this group have on the development of urban logistics?

Question 2: How important is each stakeholder group to urban logistics systems?

These same questions were applied to 4 separate themes, as shown in Table 7:

Table 7 Definition of themes used for the analysis

Theme	Definition
Positive societal development	The level of investment in the population so that the latter sees its full positive potential emerge.
Environment's respect	Is based on an attitude respectful of the future of man on planet Earth and of the limited resources in the long term.
Use of SMART means	Use of modes of transport that incorporate new information and telecommunications technologies.
Safety of goods and people	Being able to keep people and transported goods safe during any distribution journey.

Phase 3 Data aggregation

The classification is based on the determination of the powers and interests scores of each stakeholder. The score profiles determine the classification of the clusters of stakeholder groups. Scores are calculated using data collected through a questionnaire detailed in the 2nd phase. After grouping the data, we aggregated the inputs by theme. To do this, we calculated the minimum value, the maximum value as well as the weighted average of each

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theme grouping. Note that we work with the weighted mean values for the rest of the analysis. This means that for each actor, we retain the minimum value assigned, the maximum value and we calculate the weighted average.

After obtaining the tables of results for the 2 entries Interest and power for the 4 themes, we must now group them into an overall table. In order to group the data into a single function, we weighted the 4 themes, according to the AHP method, we ranked the order of priority of themes.

We can denote the desired function as follows (1), (2):

$$aXi + bYi + cZi + dTi; \tag{1}$$

$$a + b + c + d = 1; \tag{2}$$

$$i \in \llbracket 1; 9 \rrbracket$$

X, Y, and Z are the average values for each stakeholder expressed by interest and power for all 4 themes. For example, we calculate the mean average of the government’s interest and power, applied to the 4 themes mentioned above.

Figure 3 shows the classification of themes resulting from the AHP analysis. The result was the following:



Figure 3 Results of the ranking according to the AHP method

To ensure that the percentages are balanced and accurately reflect the results of the analysis, two post-ranking conditions were imposed using the Analytic Hierarchy Process (AHP):

- No percentage must be less than 10% to be quantified properly in the grouping function.
- Every percentage must be a multiple of 10.

Therefore, the percentage table is slightly modified and is considered as follows (Table 8).

Table 8 Used Importance of Themes in Percentage

Theme	Percent Importance %
Positive societal development	a =10%
Environment’s respect	b =40%
Use of SMART means	c =20%
Safety of goods and people	d =30%

Phase 4 Adding a third input

The goal of our work is to create decision graphs that will give us a priority ranking of stakeholders. So, to complete the Interest-Power matrix, we add a third variable, namely, efficiency. It is important to think of a third variable as long as it will make the analysis broader and more focused. Efficiency is a judgment that quantifies the level of achievement of the objectives linked to the function exercised by each player in urban logistics. The treatment of efficiency data corresponds to that used for the other two entries. The stakeholders are positioned on the decision-making function according to the 2 distinct coordinates in 3 different graphs (interest, efficiency), (power, interest), and (efficiency, power).

Phase 5 Decision graphs

The decision graph was plotted based on the results of the stages mentioned above. On a 2D surface, we draw our 2 respective inputs, which are the interest, the power, and the efficiency of each of the stakeholders, according to Table 9:

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Table 9 Table of coordinates

Stakeholders	Retained Value – Interest	Retained Value - Power	Retained Value - Efficiency
Government	2.71	2.55	2.85
Consumer	1.98	1.44	1.23
Sender	1.20	1.41	2.37
Industrial	1.88	1.92	2.57
Resident	1.91	1.07	1.06
Regulator	1.35	1.48	2.11
Logistic provider	1.45	1.26	2.51
Reversed logistics operator	1.45	1.24	2.36
Driver	1.79	2.01	2.00

For the 3 graphs we add a horizontal line $y = mean$ as shown in figure 4, figure 5 and figure 6. This latter presents the minimal value, above which the values may correspond to an important stakeholder.

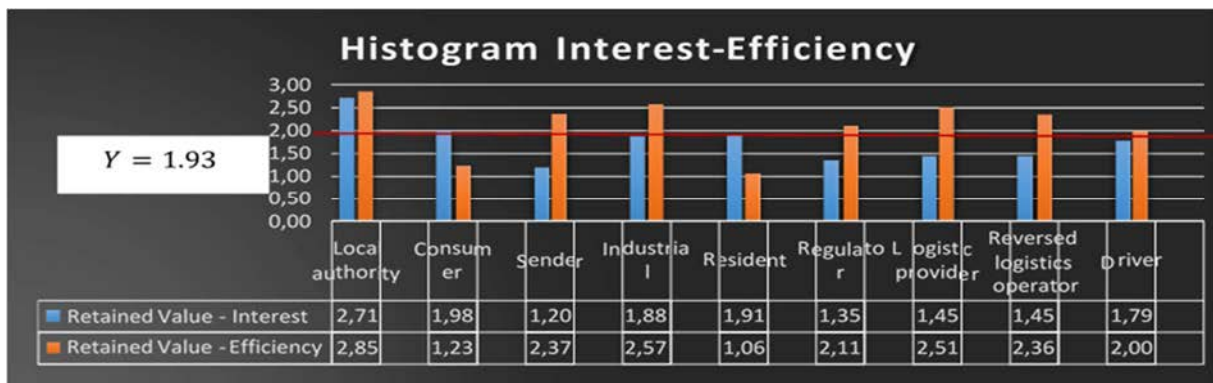


Figure 4 Interest-Efficiency Histogram

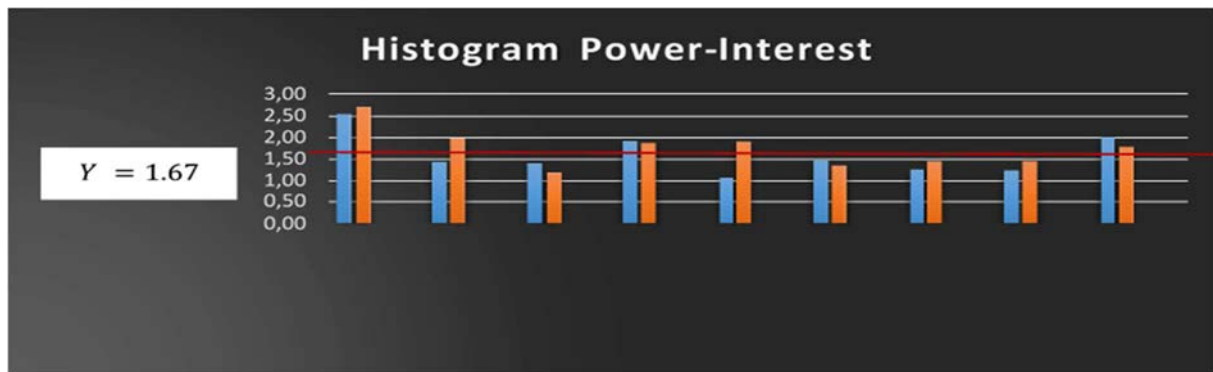


Figure 5 Power-Interest Histogram

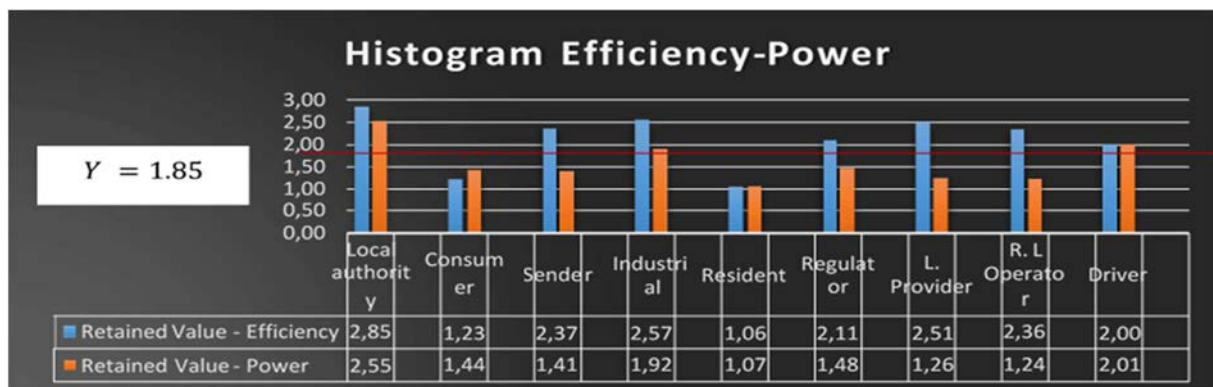


Figure 6 Efficiency-Power Histogram

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What is significant for us is the values of powers, interests and efficiency, which exceed the fixed average. We will keep all stakeholders that exceed this threshold for both entries per graph. It is enough for both values to cross the line $Y = Mean$, for it to be considered as an important actor (Mean value which changes according to the order of the histograms).

The basic idea was to compare the results of the graphs, except that in our case the same stakeholders are highlighted. The 3 histograms show that the most important stakeholders are: Government, Industrials or Manufacturers, and Drivers.

3.4 Discussion of results

The previous analysis has shown that drivers, industrials and the authorities represented at this level by the government are the 3 actors on which we must act in the first place in order to better manage urban logistics. The proposed solutions must concern these latter in the first place, once these actors have been treated and concluded to do their tasks correctly, we can move on to the next one.

This judgment seems logical and appropriate to us, since, in Morocco, the government decides on the state of the cities and the logistics. It is an enabler who not only makes decisions on all terms but who has the right to establish a basis of methods and results while controlling the process. The importance of manufacturing and industrial companies stems from the fact that production regulates the entire system of distribution of goods, whether in terms of quantities, frequencies of shipments or transfers, the positioning of intermediate stocks or even reconciliation stock with customers.

4 Conclusions

In recent years, the importance of stakeholders in urban logistics management has become increasingly recognized, and there is a growing need to better understand the roles and interactions of these actors in the delivery chain.

In this paper, we undertook a comprehensive study of stakeholders in urban logistics management. We began by defining the concept of stakeholders and categorized them based on their level of involvement in decision-making since it is a necessary first step in developing effective strategies for urban logistics management. After gathering and comparing the opinions of the authors, we delved deeper into the study by determining the attributes of each actor to better understand their role and positions. Our study went beyond a simple categorization of stakeholders and utilized a graphic study based on a questionnaire to categorize and classify the stakeholders. This approach allowed us to identify and prioritize key stakeholders and better understand their impact on the logistics system.

From this study, we can conclude that prioritizing certain actors is necessary when presenting an action plan for urban logistics management. The study revealed two important realities:

The first reality: the consumer, although not integrated into decision-making, is the pioneer of the entire delivery chain and their behaviour should be taken into account.

The second reality: the government, industrialists, and drivers are the three main actors in this chain, with the government being the most important as they directly manipulate urban transport due to their environmental and urban obligations.

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On the relationship between cash flow bullwhip and the company performance: study of the Moroccan detergent products branch

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Keywords: cash flow bullwhip, bullwhip effect, COVID-19, supply chain, performance.

Abstract: The COVID-19 pandemic had a significant bullwhip effect, which resulted in a cash flow bullwhip (CFB) in the Moroccan FMCG industry. As illustrated by a previous study, some companies were more affected by CFB than others. This indicates that CFB could be correlated to some specific aspects or characteristics of these companies. The objective of this article is to thoroughly examine the connections between CFB control and the company's internal control performance, financial performance, and supply chain performance. Therefore, a field study is conducted on the producers of detergent products. The results confirm that some performance criteria are directly correlated to the degree of exposure to CFB. In fact, a firm is able to regulate CFB when it has an effective internal control system, a reliable supply chain, and strong financial efficiency. However, the relative importance of these performance criteria is not evident. This opens the opportunity to develop a multi-criteria model that could hierarchize the different performance criteria.

1 Introduction

The previous research study demonstrated that the COVID-19 pandemic caused a great bullwhip effect that led to cash flow bullwhip (CFB) in the Moroccan FMCG sector [1]. CFB is a cash flow distortion that can be explained by the fact that the amplification of orders produced by the BWE does not reflect actual demand, which decreases the flow of products, and results in a high cost of stock holding, a cost of opportunity, and a greater need for working capital [2].

For these impacted companies, the cash flow conversion cycle's unpredictability raised their need for working capital and constrained their ability to finance themselves. To deal with this circumstance, those businesses turned to alternative sources of funding, such as their equities or bank loans, to support their operating activity [1].

Still, the degree of exposure of these companies to CFB has been different [1]. This research aims to explore the reasons that made certain companies less impacted than others. For this purpose, this research proposes to study the correlation between a company's performance and the level of CFB control. The selected performance attributes are related to the components of the cash conversion cycle, namely, inventory, accounts receivables, and accounts payables.

1.1 Problem statement

Due to COVID-19, FMCG Moroccan companies suffered from CFB. The influence of CFB on the company's cash flow is described by the fluctuation in CCC components, such as inventory flow periods and accounts receivable delays. As a result, the more the flow times fluctuate and lengthen, the longer it would take the organization to collect money, severely impacting its cash flow. Despite being profitable, CFB-affected companies are being kept hostage by their inability to finance their operations. They are forced to seek outside financing as a result, and the cost of doing so has an impact on their profitability [1].

As demonstrated in a previous study, the degree of a company's exposure to this CFB is different [1]. In order to understand what makes a company more resilient than others, a field study is conducted on a specific category of companies operating in the same branch, which is the production of detergent products.

Given that the CFB impacts the CCC and that CCC is mainly related to supply chain, financial and internal control activities, this research work aims to analyze in depth the relationship between CFB control and the company performance on the supply chain side, financial side, and internal control side.

1.2 Research objectives

The aim of this research is to determine which performance dimension contributes to CFB control. Thus,

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through a field study, the objective is to answer the following research questions:

- What characterize the resilient companies from the most affected ones?
- Can supply chain performance impact the degree of exposure to CFB?
- Can financial performance impact the degree of exposure to CFB?
- Can internal performance impact the degree of exposure to CFB?
- Which performance criteria are most related to CFB control?
- Is there a combination of performance criteria that can lead to a specific degree of CFB control?

1.3 Research contributions

This research is of major interest to companies which are suffering from CFB given that it will give deep insights into the relationship between CFB exposure and the 3 dimensions of performance. It will give the managers a better understanding of the lever that could be used to prevent and control the CFB, which will contribute to the financial safety of their firms, especially in the context of major crises such as the COVID-19 pandemic.

For researchers, this article offers another angle to analyze the CFB and to identify potential levers to control CFB, through the study of the correlation between a company's performance and its CFB control.

On the other hand, by examining the particularity of the phenomena in relation to large crises, which can take the shape of a pandemic or other comparable event, this paper, is intended to be a contribution to the different research that has been conducted on the phenomenon of cash-flow bullwhip.

To meet the various objectives assigned to this research work, the first part is dedicated to a brief literature review of the Cash flow Bullwhip and the presentation of the three performance dimensions with the criteria that will be used for the survey guide. The second part is for the description of the study design and the presentation of the primary results. The third part is devoted to the analysis and discussion of the results, and to propose future research perspectives.

2 Theoretical basis

2.1 CFB literature review

CFB is the disruption of cash flow caused by the bullwhip effect [2]. This cash flow distortion directly impacts the working capital requirements of the company, because it deteriorates the cash conversion cycle [3].

Before the introduction of this notion by Tangsuehveeva & Prabhu in 2013, many research studies focused on the financial aspect of the supply in general, and the cash conversion cycle precisely. In this regard, Farris presented the effective methods for managing the cash to cash cycle and underlined the significance of the cash to cash cycle as

a metric to evaluate the performance of the supply chain [4]. By analysing the standard deviations of the receipt, disbursement, and net flows for each period within a planning horizon, Tsai provided a modelling of the cash flow risks related to the supply chain [5]. Tsai recommended using an asset-backed securities (ABS) policy to finance accounts receivables in order to reduce the time it takes to convert money into cash and the likelihood of collection. Randall and Farris offered a way for enhancing the supply chain by sharing weighted average capital costs with trading partners and working together to control cash-to-cash cycles [6]. According to Hofmann and Kotzab, collaborative techniques are more effective than delaying suppliers' payments or collecting receivables early to increase the working capital for supply chain partners [7]. Tsai showed that businesses, particularly those with limited financial resources, suffer cash collection risks when attempting to increase sales. Tangsuehveeva and Prabhu proposed a stochastic forecasting model that combines a Bayesian model for each individual customer's payment behaviour with a Markov chain model for the company's overall payment behaviour across all of its customers [8]. This has a very accurate forecast and is not dependent on the BWE. Tsai demonstrated how cost structure affects cash flow risk and how Just in Time production philosophies and new technologies can help to lower this risk [9]. Goodarzi developed a simulation model that includes a multi-stage supply chain, as well as a centralized and decentralized supply chain, to study the effects of the bullwhip effect's causes and the effect of their interactions on the CFB [10]. Despite the fact that each link in the chain employs an "Order Up To" replenishment strategy, their findings imply that the CFB can be found in both centralized and decentralized supply chains. Serrano looked at how order fluctuations affected supplier payment deadline variability at the supply chain level, as well as how they affected risk and how it spread upstream in the chain [11]. In order to examine working capital optimization in a two-echelon supply chain with one supplier and one retailer, Peng and Zhou created three models based on various supply chain collaboration levels [12]. Despite the degrees of cooperation, the authors recommend extending the payment time whenever the retailer's discount rate is greater than the suppliers. Using a system dynamics simulation model and genetic model, Badakhshan et al., created a simulation-based optimization strategy. For each SC member, the best financial and inventory choice criteria are discovered to lower the overall cost, BWE, and CFB [13]. Using 238 semiconductor businesses as a sample, Prabhu looked into the presence of CFB and the conventional bullwhip effect (BWE) from 2010-Q1 to 2020-Q4 [14]. Authors discovered that a semiconductor business's CFB and BWE are positively correlated with procurement and payment lead times, and negatively correlated with company size, the degree of seasonality in demand, and the company's payment policy conservatism.

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Lamzaouek examined the effects of digital technologies on CFB and discovered through a systematic literature review that a number of technologies can positively contribute to containing this phenomenon by addressing its operational causes, namely the accuracy of forecasts, batch orders, price volatility, rationing games, and lead times [15]. During the COVID-19 epidemic, CFB was examined for its effects on the financial health of Moroccan FMCG companies. According to the survey's findings, SMEs and very small enterprises were the ones who suffered most from the effects of CFB due to the rise in working capital requirements and decline in cash flow. By enhancing internal control mechanisms at the level of the processes of purchasing, inventory management, sales, and cash management, the authors suggested an organizational strategy to handle this issue [1].

According to X. Chen et al., the growth in CFB is positively connected with the increase in the price cross-sensitivity coefficient, the same research examined the effect of market share and price cross-sensitivity coefficient on the CFB [16]. Prabhu looked at how credit risk affected the cash-bullwhip in the supply chain. The findings of this study show that taking credit risk into account increases the amounts of cash and accounts payable that are transferred from downstream members to upstream members. This study also demonstrates how, when credit risk is taken into account, the account receivable turnover index accurately depicts the cash-bullwhip effect of every link in the supply chain [17].

2.2 Performance models – a brief literature review

Many authors defined the term performance through the years. In this regard, for Miles, performance is the ability of the organization to achieve minimal satisfaction of the expectations of its strategic clients [18]. For Chandler performance is an association between functional efficiency and strategic effectiveness [19]. Functional efficiency focuses on enhancing the company's offerings, purchasing, manufacturing process, marketing strategy, and employee relations. Gaining an advantage over rivals by entering a market that is experiencing growth or leaving a market that is experiencing a fall is the definition of strategic effectiveness. For Lorino, performing in the company is everything that, and only that, contributes to improve the value-cost couple (conversely, performance is not necessarily what contributes to reducing the cost or to increase the value in isolation) [20]. That's said multiple models have been introduced in the past to evaluate the performance of an organization. Campbell considers that the measurement of performance happens through the setting of criteria which are quantitative and/or qualitative. In this sense, he put up a list of around thirty performance standards. 57% of the criteria include reference to social and human elements. 13% is directly related to financial and economic factors. The rest is a mixture of strategy, production, environmental factors, etc [21]. Steers

provides a multifaceted viewpoint that links the following three ideas: Optimization of goals, the systemic perspective, and the significance of workers. The 29 components that make up the Steers analytical framework are divided into four sets, which are as follows: The characteristics of the organization, the characteristics of the external and internal environment, the characteristics of the employees, and the management policies and practices [22]. Along with economic factors, Welge and Fressman emphasized the significance of social and human parameters. their analysis revealed that economic and financial factors should be prioritized when evaluating a company's overall success [23]. Peters and Waterman identified eight characteristics of excellence through their model, which can be summed up as follows: action orientation, listening to customers, autonomy and entrepreneurship, productivity through staff motivation, the law of shared values, stick to what you know how to do, a simple and light structure, flexibility in rigor [24]. Quinn and Rohrbaugh highlighted three dimensions in their model [25], internal/external objectives, flexibility and control, and means/results. Rambhujun proposed twenty-eight criteria for assessing the success of businesses, categorized along five axes: management factors, sales elements, customer interaction factors, production factors, and talents aspects [26]. In the Model of Pascal and Athos, business performance is based on six elements, which are as follows: System, staff (people), style (behaviour of the boss and his subordinates), staff (personnel), strategy (way of allocating resources over time to achieve the intended objectives), and skills (know how). The Lynch and Cross model offers an integration of strategic and operational indicators. For these authors, business strategy cannot neglect operational data, a clear link must exist between the two. Six performance criteria are listed in Fitzgerald, Johnston, Brignall, Silvestre, and Voss's matrix of determinants: financial performance criteria, competitiveness, service quality, flexibility, resource efficiency, and innovation. The Model of Kaplan and Norton makes it possible to assess performance in four areas, which are the customer vision, the financial vision is notably that of the shareholder, the internal process vision, and the ability for a company to innovate, improve and learn. The four-dimensional model of Morin, Savoie and Beaudin is articulated around the following axes: the value of human resources, economic efficiency, the legitimacy of the organization, the sustainability of the organization. In the model of Atkinson, Waterhouse and Wells, the authors present a model of organizational performance based on the stakeholder approach. These stakeholders are, for most organizations, investors, employees, customers and the community. According to the Adams and Neely's Prism and Success Maps, because the performance is not flat, the author wants to demonstrate its complexity. It is crucial to examine it from several angles connected by the Performance Prism in order to comprehend it completely. Additionally, this model is built around five axes that

describe the company's overall vision: Stakeholder contribution, strategy, procedures, and resources (both tangible and intangible).

2.3 Company performance and CFB

From the previous literature review, it's obvious that there are various dimensions that can be used to evaluate the company's performance. In the following, three dimensions—financial, supply chain, and internal control—will be used to evaluate performance of targeted companies. This choice is justified by the fact that the CFB directly concerns the cash conversion cycle, and that the 3 components of the CCC, namely inventory turn, accounts receivables, and accounts payables, are dependent on the policy and company actions on the logistical, financial and internal control aspects. Indeed, a company's ability to provide exceptional customer service will enable it to have strong inventory flow, which will help it maintain an ideal inventory level. In addition, a good internal control system will allow the company to have good control of the risks relating to accounts receivables and accounts payables. Ultimately, a balanced financial structure will make the business more resilient to cash flow disruptions.

That's said, in order to assess the performance of these companies in relation to the three dimensions retained, it is necessary to define the adequate standards and reference systems. In this regard, the SCOR reference framework is chosen for the evaluation of logistics performance, the COSO reference framework for internal control performance, and the ratio analysis method for the evaluation of financial performance. This choice is justified by the completeness and reputation of these standards (Figure 1).

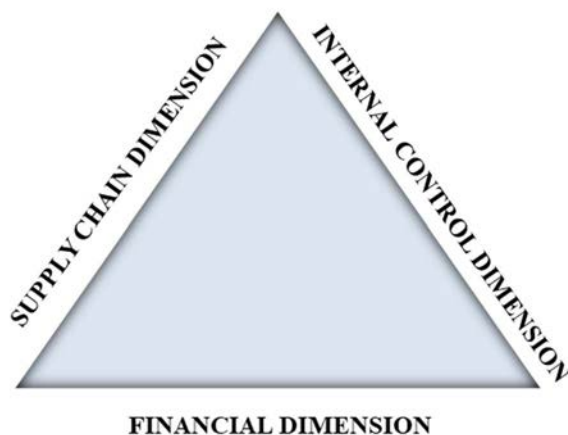


Figure 1 Performance evaluation model

3 Methodology

This study is a follow-up to the previous investigation into the effects of CFB on Moroccan FMCG firms during the COVID-19 crisis [1]. It is conducted on a homogeneous sample of detergent-producing enterprises. These

companies were chosen from the earlier research participants.

The goal is to investigate how the CFB's level of control, is influenced by these companies' performance levels on the financial, logistical, and internal control dimensions.

In order to respond to the many questions posed for this research work, a quantitative study has been carried out. The research technique that was used, the findings and their interpretation, as well as our recommendations and conclusions are all presented in the paragraphs that follow.

3.1 Research methodology

3.1.1 Research design

It is crucial to go through a design phase acting as a cartography strategy for our study in order to have the answers to our research questions. In this regard, we decide to carry out a quantitative study on Moroccan enterprises that make detergent goods. A survey of a target population was carried out during June and July 2022 for this reason.

3.1.2 Target population

The term "population" in research refers to all the items connected to the research purpose and used to build conclusions and suggestions [27]. For this research, the target population concerns all the companies producing detergent products. The decision to engage in this particular branch of business was not arbitrary, given that this type of product's demand pattern saw significant fluctuations.

3.1.3 Sampling

Sampling is the process of choosing a portion of a research population for analysis. The size of the sample depends on the objective of the research. The sample for this study consists of the detergent-producing businesses that were involved in the earlier investigation of the effects of CFB on Moroccan FMCG firms [1].

Seven companies make up this sample, which seems to be the ideal balance between the study's complexity and degree of representativeness.

3.1.4 Data collection

To collect the necessary data for this study, questionnaires were administrated by emails to the representatives of the targeted companies. The targeted respondents hold managerial positions in finance, supply chain, and executive management. Financial documents have been recovered from these companies.

3.1.5 Summary of variables

In what follows, a summary of the selected variables from the survey that was conducted. These variables represent performance criteria's according to the adopted performance model (Table 1).

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Table 1 Summary of the survey's variables

Performance dimensions	Performance criteria's	Performance sub criteria's	Description
Internal Control Performance	Control Activities	Control Activities	Existence of rules and procedures which aim to provide reasonable assurance that the instructions of the management to control the risks likely to affect the achievement of the objectives [28,29].
	Control Environment	Control Environment	Existence of policies, processes, and institutional structures for internal control implementation across the board [28,29].
	Risk Assessment	Risk Assessment	Existence of iterative methods for locating and analyzing risks that could compromise a company's goals [28,29].
	Information and Communication	Information and Communication	Existence of data necessary for internal control operations [28,29].
	Monitoring	Monitoring	Existence of an evaluation intended to confirm the existence and proper operation of each of the five internal control principles and the components [28,29].
Supply Chain Performance	Supply Chain Reliability	% of Orders Delivered in Full	Percentage of orders where the customer receives every item in the quantities promised [30,31].
		Delivery Performance to Customer Commit Date	The proportion of orders that are delivered on the day that the customer originally agreed upon [30,31].
		Perfect Condition	Percentage of orders that are successfully completed, configured correctly, and accepted by the customer and are delivered in an undamaged state [30,31].
		Documentation Accuracy	Percentage of orders with timely and accurate invoices, bills of lading, packing slips, and other supporting documents [30,31].
	Supply Chain Responsiveness	Cycle Time	The regular average actual cycle time for completing customer orders [30,31].
	Supply Chain Flexibility	Upside Supply Chain Flexibility	The number of days needed to supply a 20% increase in quantity that was not accounted for [30,31].
		Upside Supply Chain Adaptability	The amount given that can increase by a maximum sustainable percentage in 30 days [30,31].
		Downside Supply Chain Adaptability	At 30 days before delivery, the quantity ordered can be reduced without incurring inventory or cost penalties [30,31].
	Supply Chain Costs	Cost of Goods Sold	Cost of purchasing raw ingredients and creating final goods including direct and indirect costs (overhead) [30,31].
	Supply Chain Asset Management	Days Sales Outstanding	The number of days in which a sales balance is outstanding [30,31].
		Inventory Days of Supply	The stock's quantity, measured in days of sales [30,31].
		Days Payable Outstanding	The period in days from the moment labour, materials, and/or conversion resources are purchased until cash payments are required [30,31].
		Cash Conversion Cycle	The amount of time it takes for an investment to make its way back into a business after being used to purchase raw materials [30,31].
Financial Performance	Financial Debt	Self-financing rate	The self-financing rate quantifies the portion of investments that the business is able to fund solely through its economic activities [32].
		Solvency ratio	Assessing a company's financial health by selling assets to pay off all debts. [32].
		Debt ratio	The debt ratio compares equity capital to that provided by financial institutions [32].
		Minimum Payback Period	Measures the company's ability to repay all of its structural debts by its own means [32].
		Weight of interest	The weight of interest is an indicator of the company's future difficulties [32].
	Financial Profitability	Revenue growth rate	Percentage of the company's revenue that fluctuated [32].
		Production growth rate	Percentage of the company's production that fluctuated [32].
		Gross profitability rate	Measures the company's profitability and profitability [32].
		Economic rate of return	Measures the company's profitability and profitability [32].
		Asset rotation	Measures the company's ability to generate revenue for every dollar invested in the company [32].
	Financial Efficiency	Margin rate	Reflects the consequence of actions taken to reduce costs and maximize sales [32].
		Working Capital Requirements	Measures, in number of days, the importance of the working capital requirements [32].
			Current ratio
Financial Liquidity	Acid-test ratio	Comparing short-term assets to short-term liabilities to determine cash [32].	

4 Result and discussion

4.1 Descriptive analysis of variables

Following are the results of a primary examination of the survey's data:

- The radar chart (Figure 2) shows that company 2 is the most performing on the internal control side, followed by company 1. The company 3 has the weakest score due to a poor risk assessment, control environment, information and communication, and monitoring. Risk assessment is very weak for companies 3, 5, and 6.
- Looking at the supply chain reliability of these companies, it's obvious that company 1 and 2 are better performing comparing to the rest of companies. That's the case for the orders delivered in full, the commitment to delivery date, and the perfect condition of deliveries (Figure 3).
- For the responsiveness of the supply chain, the comparison of companies' cycle time shows that company 2, 1, and 4 have the shortest cycle. Company 3 has the highest cycle with more than 40 days.
- The upside supply chain flexibility, the upside supply chain adaptability, and the downside supply chain adaptability are the three metrics used to assess supply chain flexibility. According to the findings, company 2 has the most upside flexibility, while firms 5 and 3 perform better in terms of downside and upside adaptability.
- For the supply chain costs, results show that companies 3 and 7 have the least costs, comparing to the rest of firms.
- For the supply chain asset management, performance is compared based on four metrics: Days Sales Outstanding, Inventory Days of Supply, Days Payable Outstanding, and Cash Conversion Cycle. Results show that companies 2 and 1 are the better performing, while companies 6 and 7 are the weakest ones.
- At the debt ratios level, companies 2 and 1 present the best self-financing rate and solvency ratio. Company 1 is better at the ratio of weight of interest. On the other side, company 6 suffers from a high debt ratio and weight of interests, while companies 3 and 4 have the lowest self-financing capacity.
- At the level of the efficiency ratio, the working capital requirement is very high for companies 7, 6, and 3, while companies 2 and 1 are better performing on this side.
- For the profitability ratios, results show that companies 2 and 1 are more profitable than the other companies. Companies 3 and 4 are the companies with the lowest growth rate of production and revenue.
- Liquidity ratios analysis shows that companies 6, 7, and 3 have the lowest performance level.
- Looking at the coefficient of variation of cash flow, it's clear that companies 6 and 7 have a highest variation, comparing to the rest of companies.
- The preceding results show that the performance of the seven companies is heterogeneous for the 3 dimensions studied. Results also shows that company 6 have the most varying cash flow. Therefore, a correlation analysis is needed to analyse in depth the relationship between the different performance attribute and the variation of cash flow (Figure 4).

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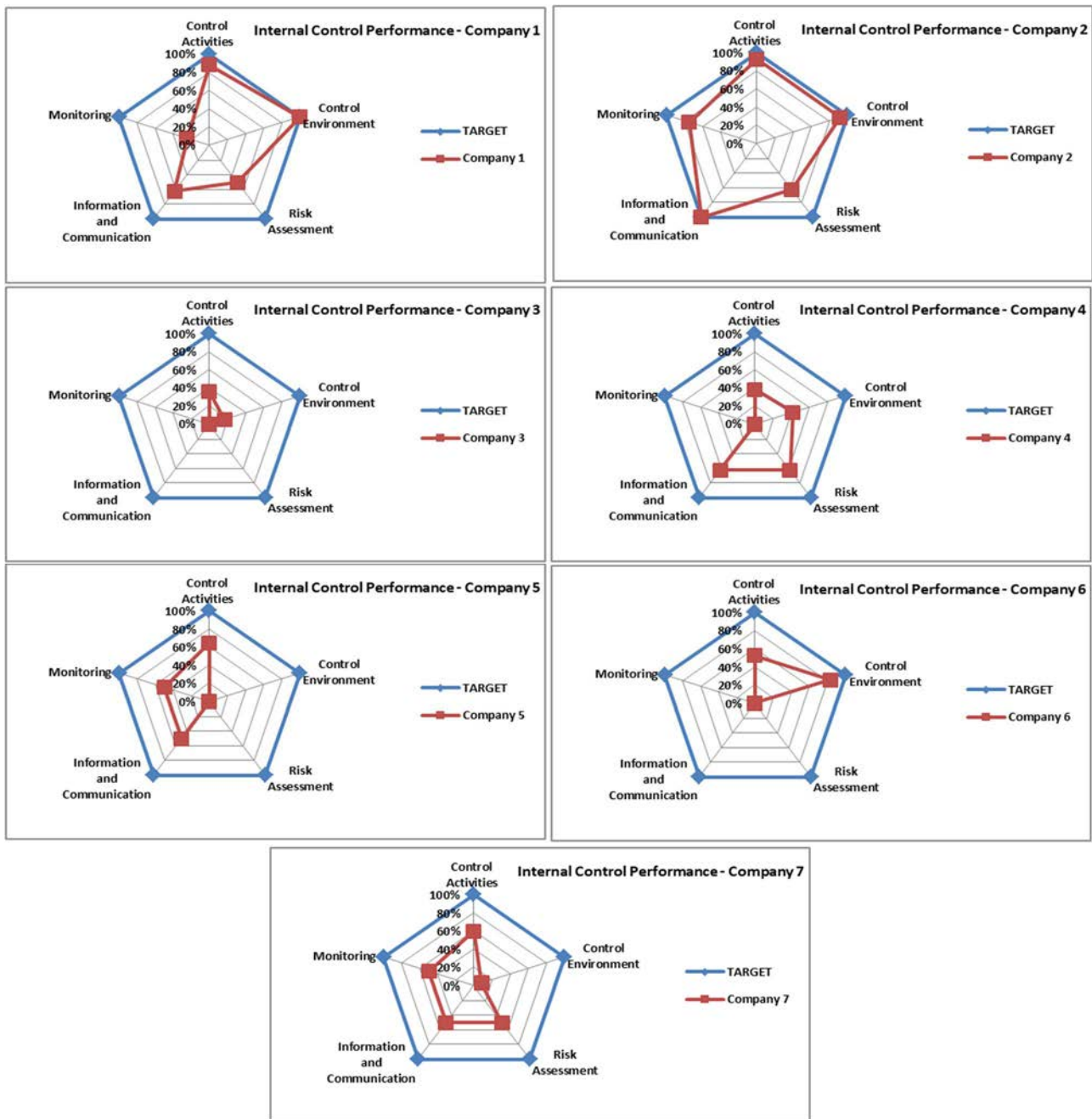


Figure 2 Internal control performance of the companies studied

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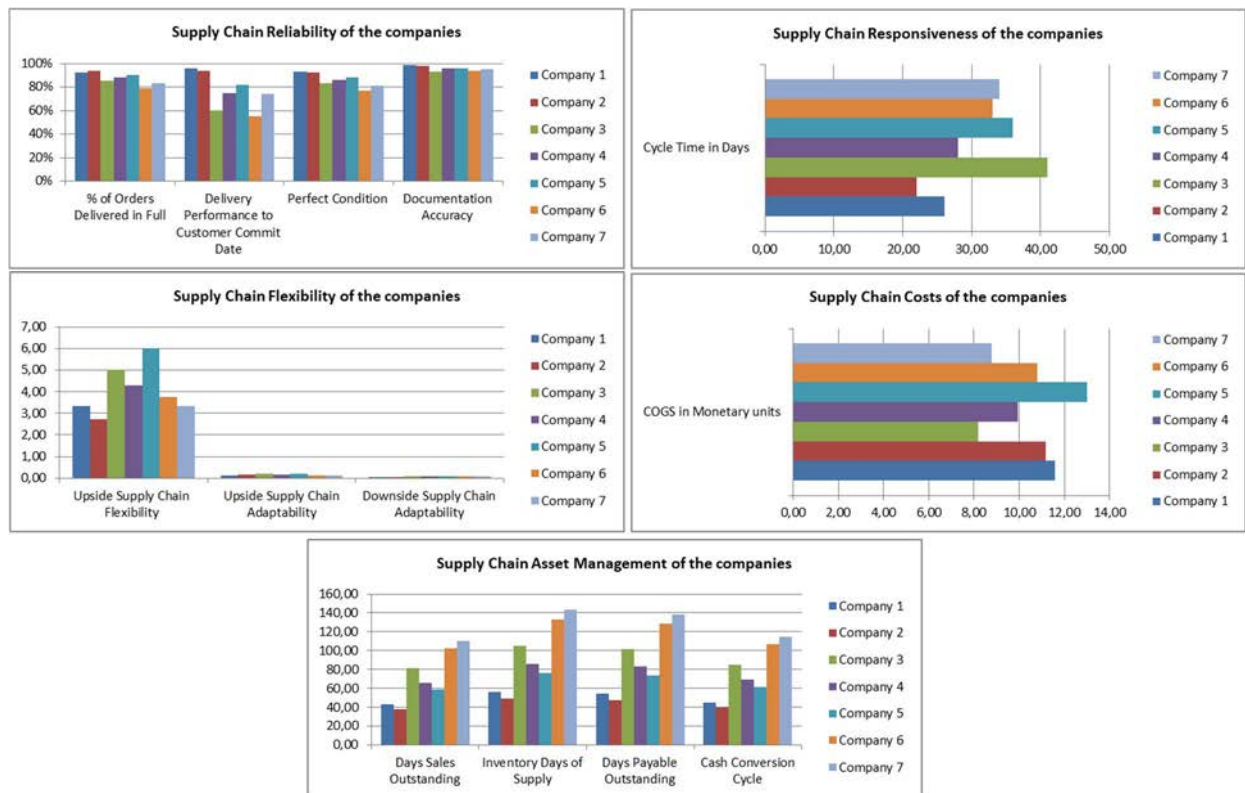


Figure 3 Supply Chain performance of the companies studied

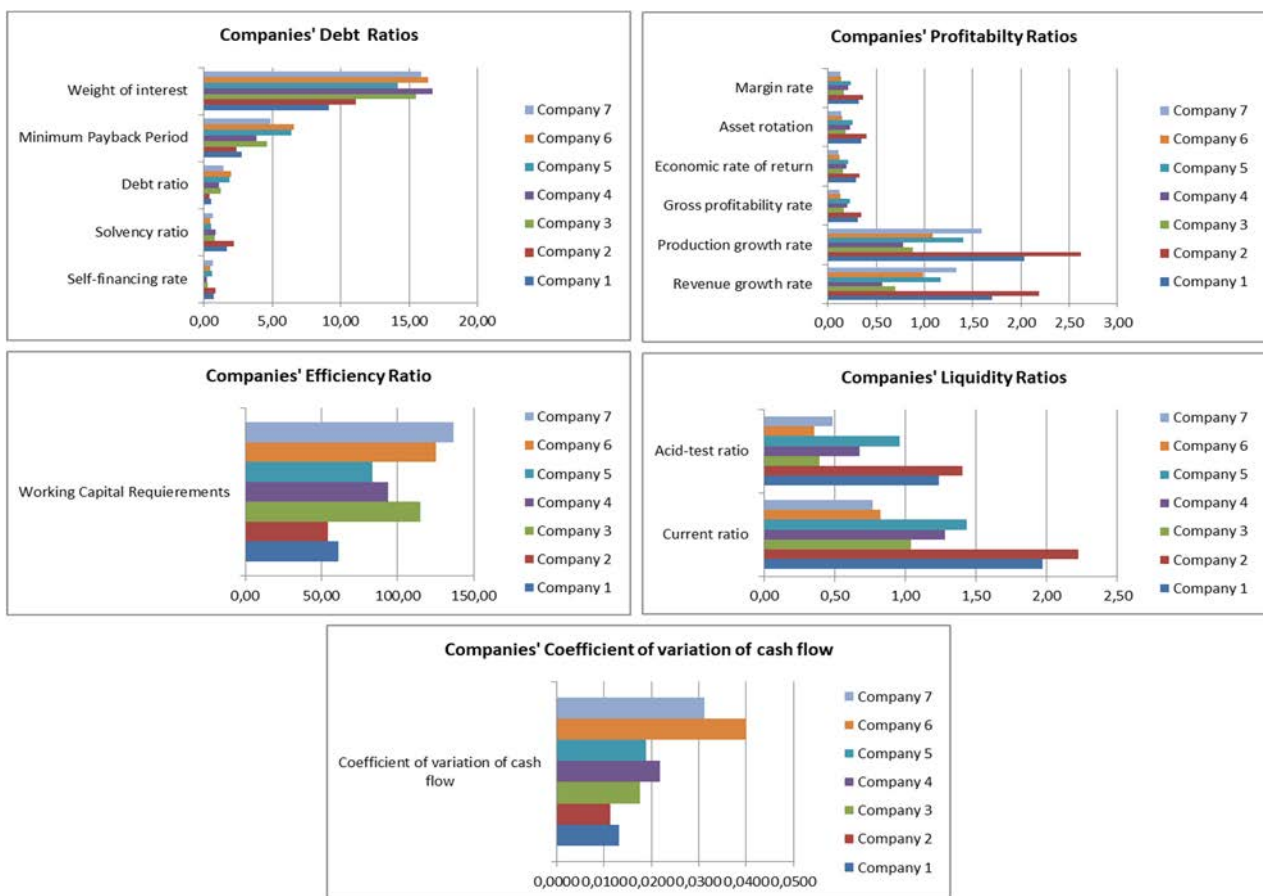


Figure 4 Financial performance of the companies studied

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4.2 Principal component analysis

Principal component analysis (PCA) has been done on the variables acquired from this study in order to thoroughly assess the survey's results. The results of the PCA that was performed in connection to the study questions are presented in the sections that follow.

For each PCA the KMO and Bartlett's Test, the sum of the explained variance, and the component plot are computed. In this regard, the outcomes of all KMO and Bartlett's Tests demonstrate the appropriateness of the sample and disprove the hypothesis that the matrix is an identity matrix by having sampling accuracy more than 0.5 and significance lower than 0.0005.

4.2.1 Can internal control performance impact the control of CFB?

A PCA is conducted, to establish the degree and nature of the relationship between the following variables: Control Activities, Control Environment, Risk

Assessment, Information and Communication, Monitoring, and Cash Flow Coefficient of variation (Figure 5).

The resulting component plot indicates that there is a negative correlation between the Cash Flow Coefficient of variation, and the following variables: Control Activities, Risk Assessment, Information and Communication, and Monitoring. It's also obvious that Control Activities, Risk Assessment are positively correlated. These results means that companies with higher performance on control activities, risk assessment, monitoring, and information and communication tends to have lower cash flow variability, and controls more the CFB than other companies.

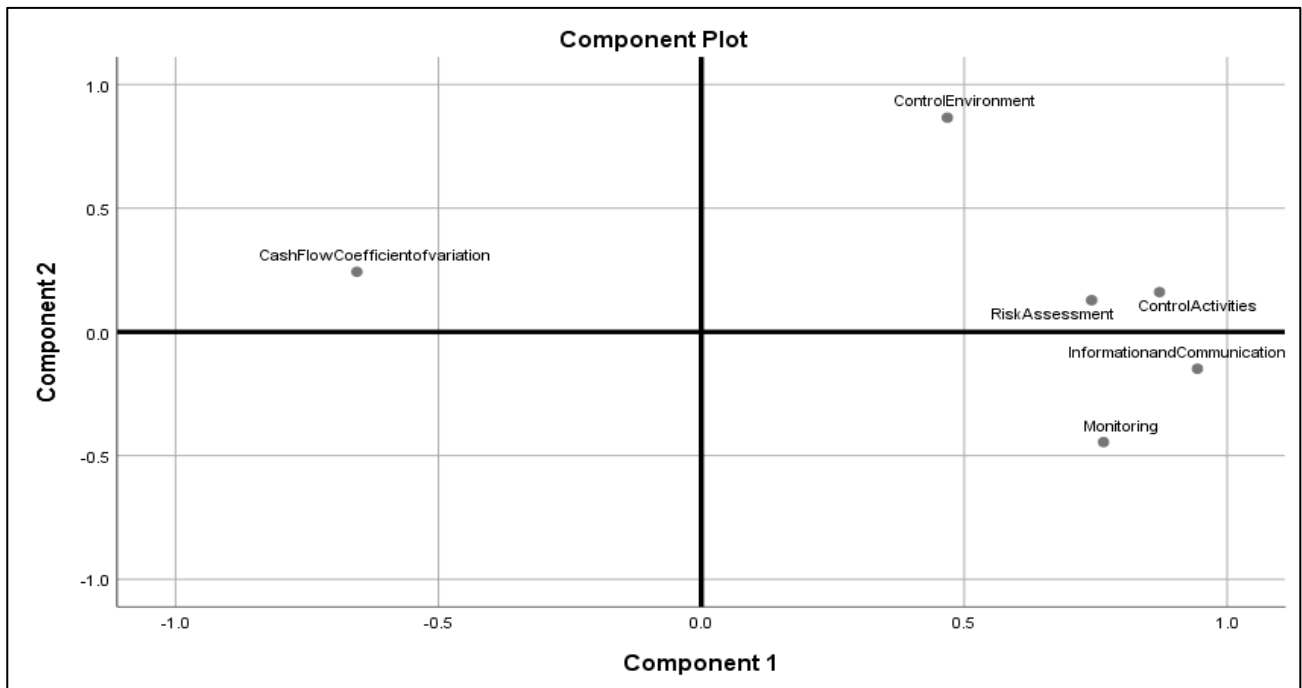


Figure 5 Component plot of the PCA n°1

4.2.2 Can supply chain performance impact the control of CFB?

A PCA is conducted, to establish the degree and nature of the relationship between the following variables: % of Orders Delivered in Full, Delivery Performance to Customer Commit Date, Perfect Condition, Documentation Accuracy, Cycle Time, Upside Supply Chain Flexibility, Upside Supply Chain Adaptability, Downside Supply Chain Adaptability, COGS, Days Sales Outstanding, Inventory Days of Supply, Days Payable Outstanding, and Cash Conversion Cycle, and Cash Flow Coefficient of variation (Figure 6).

The resulting component plot indicates that there is a negative correlation between the Cash Flow Coefficient of variation, and the following variables: % of Orders Delivered in Full, Delivery Performance to Customer Commit Date, Perfect Condition, and Documentation Accuracy. These results means that the more the supply chain of a company is reliable the lower cash flow variability is, and therefore the CFB is more controlled.

On the other side, there is a positive correlation between the Cash Flow Coefficient of variation, and the following variables: Cycle Time, Days Sales Outstanding, Inventory Days of Supply, Days Payable Outstanding, and

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Cash Conversion Cycle. These results means that management tends to have lower cash flow variability, and companies with higher performance on supply chain asset controls more the CFB than other companies.

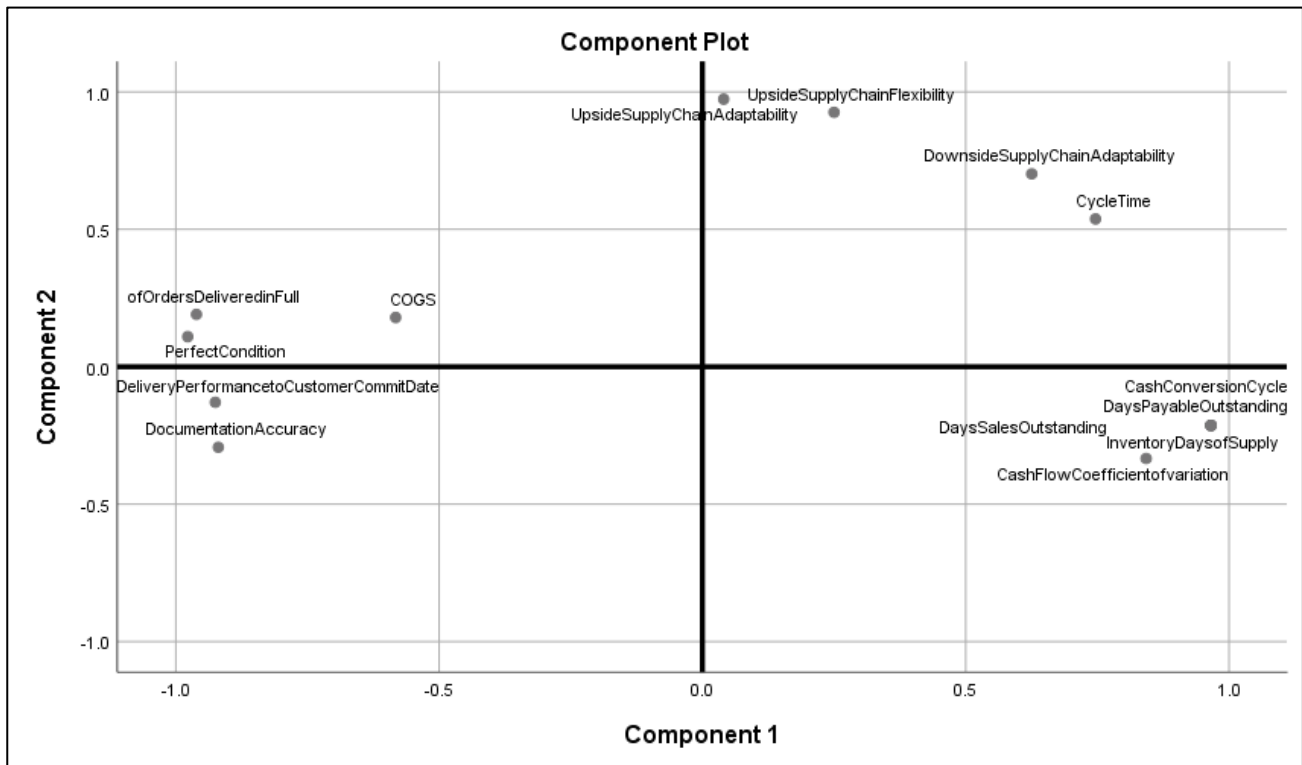


Figure 6 Component plot of the PCA n°2

4.2.3 Can financial performance impact the control of CFB?

A PCA is conducted, to establish the degree and nature of the relationship between the following variables: Self-financing rate, Solvency ratio, Debt ratio, Minimum Payback Period, Weight of interest, Revenue growth rate, Production growth rate, Gross profitability rate, Economic rate of return, Asset rotation, Margin rate, Working Capital Requirements, Current ratio, Acid-test ratio, and Cash Flow Coefficient of variation (Figure 7).

The resulting component plot indicates that there is a negative correlation between the Cash Flow Coefficient of variation, and the following variables: Self-financing rate, Solvency ratio, Revenue growth rate, Production growth rate, Gross profitability rate, Economic rate of return, Asset rotation, Margin rate, Current ratio, and Acid-test ratio. These results indicate that companies with bad debt levels have more cash flow variation. This is also the case for companies with growing production and revenue.

On the other side, there is a positive correlation between the Cash Flow Coefficient of variation, and the

following variables: Debt ratio, Minimum Payback Period, Weight of interest, and Working Capital Requirements. These results means that companies that suffers from cash flow variation are those with high level of financial debt and working capital requirement.

4.3 Discussion

The analysis of the data collected from the field survey, confirms that many performance criteria are correlated to the variation of cash flow. In general, the observation is that high cash flow variation is associated with poor internal control performance, high debt ratios, lower financial efficiency, lower liquidity, bad supply chain reliability, low responsiveness, and high cash conversion cycle. Companies with good financial performance, internal control performance, and supply chain performance, seem to have a lower variation of cash flow.

Finally, it seems that some performance criteria in particular supply chain flexibility have no correlation with the variety of cash flow.

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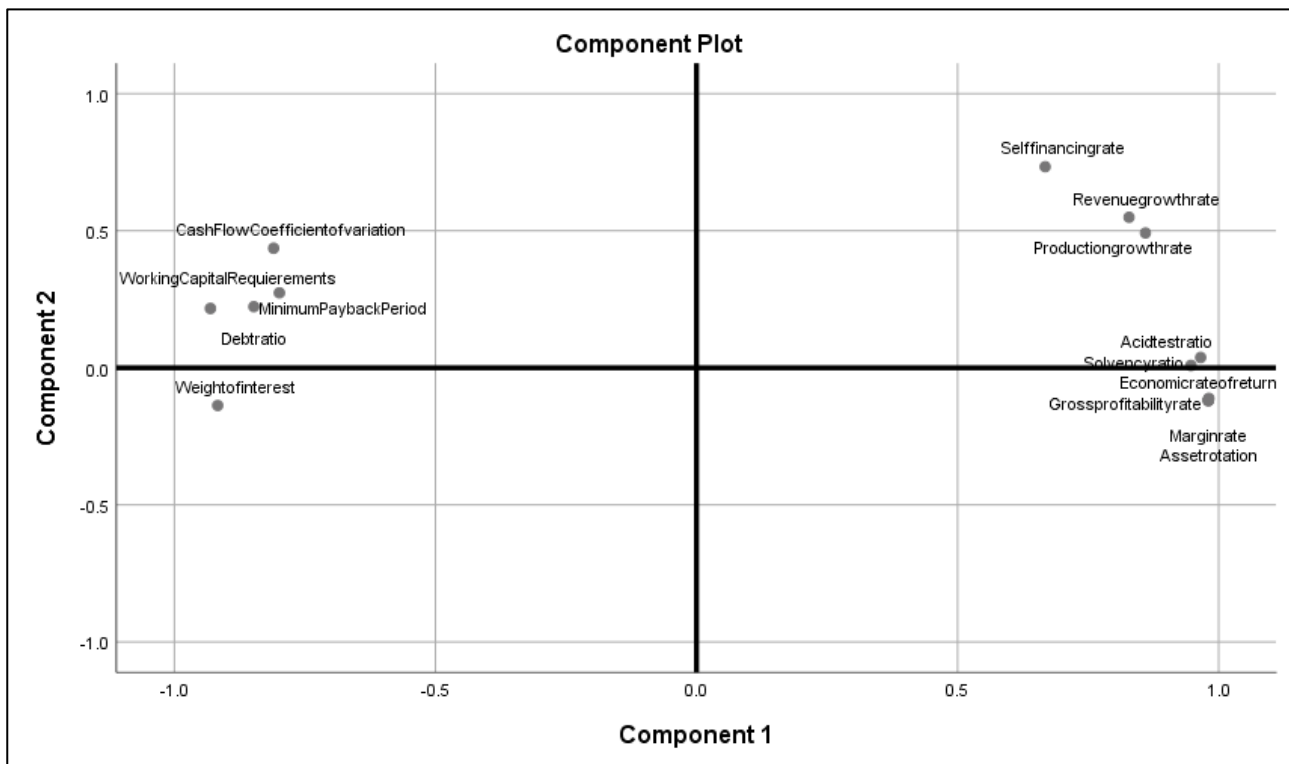


Figure 7 Component plot of the PCA n°3

5 Conclusions

The results of this study confirm the relationship between CFB control and supply chain, financial, and internal control performance. Indeed, all the companies presenting a good level of CFB control seem to be performing on the supply chain, financial, and internal control sides. In this regard, companies with reliable and responsive supply chains, are less exposed to CFB. This can be explained by the fact that the ability of supply chain to deliver the correct product, in the agreed upon time, to the correct place in the correct condition and quantity, with the accurate documentation, leads to an accelerated inventory flow, that smooth and accelerate the financial flow. Where as responsiveness will lead to a stabilized and short cycle time, that leads to less variable working capital requirement. Also, CFB is controlled when the company has an efficient internal control system, than can detect and contain the possible risks associated with the processes related to the components of the CCC (purchasing-

suppliers process, inventory management process, treasury process, sales-customer process), while insuring the existence of iterative methods for locating and analyzing risks related to these processes. Finally financially balanced companies, with good self financing capacity and low debt ratio control more CFB. This is also the case for companies with reduced working capital requirements, and companies holding enough cash on hand to cover their short-term debt. Detailed interactions between CFB and the performance criteria are presented in the table bellow (Table 2). Having said that, it is impossible to determine from actual research which performance criterion or dimension, is more important for CFB control. Because of this, it will be interesting to investigate the relative significance of each performance criterion using a multi-criteria approach in the upcoming research. This can lead to a multi-criteria mathematical model, that could explain the level of control of each company, and that could be generalized on other business sectors.

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Table 2 interactions between the CFB and the performance criteria's

Performance criteria's	Impact on CFB	How
Internal Control Performance	Control accounts payables flow time	Existence of iterative techniques for identifying and evaluating risks associated to the "Acquisition & Payment" and "Treasury Management" processes. Existence of appropriate rules and procedures to manage: <ul style="list-style-type: none"> - The synchronization between suppliers' debts recording and the supplier's deliveries. - The conformity of the invoices' payment in line with the payment authorization's rules, and contractual payment deadlines. - The cash conversion cycle and working capital requirement. - The purchase order authorization thresholds. - The verification of purchase amounts, quantities, lead times, and pricing. - The oversight of the suppliers' invoices with respect to the predetermined terms of the acquisition. - The revision of the timetable for receipts and payments. - Postponing dates for customer payments.
	Control inventory flow time	Existence of iterative techniques for identifying and evaluating risks associated to the "Inventory Management" process. Existence of appropriate rules and procedures to manage: <ul style="list-style-type: none"> - The inventory's precision to prevent irrational purchasing orders from creating excess storage. - The techniques for inventory valuation. - The inventory levels and fluctuations. - The monitoring of inventory turnover.
	Control accounts receivables flow time	Existence of iterative techniques for identifying and evaluating risks associated to the "Sales & Collections" process. Existence of appropriate rules and procedures to manage: <ul style="list-style-type: none"> - The customers' risks assessment, to prevent bad debt. - The customer credit and discounting authorization rules. - The monitoring of payments and doubtful debts. - The aged receivables. - The invoicing process in order to prevent delays of customers payments.
Supply Chain Reliability	Control inventory flow time	Every time perfect order accelerates the inventory flow and avoid flow distortions over time.
Supply Chain Responsiveness	Control inventory flow time	Stable cycle time for completing customer orders leads to controlled flow times of inventory. Which contributes to less CCC variation, and CFB control.
Financial Debt	Control accounts receivables and payables flow time	The self-financing capacity of the company and the low level of debt contribute to lower the risks of cash conversion cycle variation and consequently reduces the CFB exposure.
Financial Efficiency	Control accounts receivables and payables flow time	The lower the cycle time is, the more the Cash Conversion Cycle variation is reduced. This contributes to a better CFB control.
Financial Liquidity	Control accounts receivables and payables flow time	The more the company is liquid, the less it's fragilized by Cash Conversion Cycle variation, and CFB.

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Review process

Single-blind peer review process.

Role of meteorology in logistics planning

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Abstract: Meteorology affects every part of life. We need to know the weather conditions for our everyday life, but also for the work activities of the company. Transport is a very sensitive area that is very responsive to changing weather conditions. Each type of transport is sensitive to different weather phenomena. The article provides basic information about weather, its role in transportation, and the fact that hazardous weather phenomena can significantly affect the speed of delivery, safety and quality of transportation.

1 Introduction

Meteorology is a science with a long history [1]. Already in the distant past, our ancestors were aware of the weather's influence on their everyday life. Nations living on sea coast also were familiar with wind phenomena, which could adversely influence their sea navigation, so as fishing and the transportation of goods [2].

So let's not be surprised that it was the marine meteorology that pushed meteorology forward. Other modes of transport used the marine meteorology experience gradually [2].

Meteorologists have at their disposal tools for high-quality weather forecasting and individual values of meteorological elements, but they still have to reckon with a high value of uncertainty. In recent years, the use of meteorological satellites and meteorological radars has improved, and numerical prediction models are available with a special focus on various users of meteorological model outputs. However, in addition to high-quality forecasting tools, expert meteorologists who are able to interpret all outputs so that their information is relevant to the user are also needed.

Even though we live in the 21st century, the role of meteorology and its forecasts is still irreplaceable in the planning of activities in transport.

2 The dangerous weather phenomena

Dangerous weather phenomena are meteorological phenomena that significantly affect air traffic safety, jeopardise the flow, or even stop operations. Different dangerous weather conditions can occur in the winter and other during the summer season. The most dangerous weather situations include the frontal interface affecting the airport and its surrounding areas. A warm front is a precipitous activity, but its effects are not as dramatic as on a cold front, especially during the summer season [1]. Cold fronts arise in the wake of a developing extratropical cyclone when cooler air moves into an area of the warmer

air mass. The warmer air mass interacts with the cooler air along the frontier and typically produces precipitation. Cold fronts are frequently followed by a warm front or squall line [1,3]. The cold front is typically characterised by heavy clouds, torrential precipitation, storms associated with turbulence, wind shear, hail etc. [1,3].

Information about the occurrence of fog and, as a result, possible lower visibility also has a unique place in traffic. Fog is an aerological aerosol consisting of very small water droplets reducing horizontal visibility in at least one direction below 1 km [4]. While researching the occurrence of fog at Slovakia's international airports in the period 1998-2018, interesting information was found. The urban legend about the low incidence of days with fog at Bratislava Airport was confirmed, and the urban legend about the minimal occurrence of days with fog in summer was not confirmed. According to [5], in the period 1998-2018, fogs occurred during the year with different numbers of days at Slovakia's international airports (Figure 1).

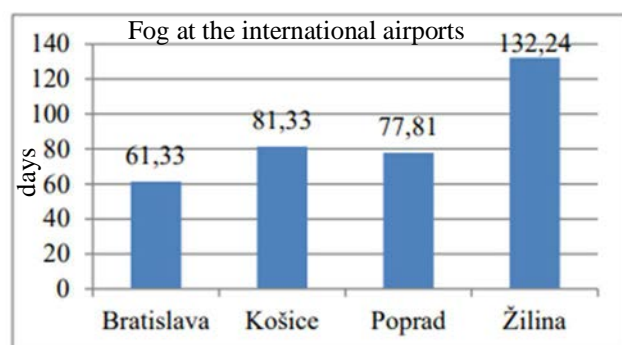


Figure 1 Average number of days with fog at the international airports for the 1998-2018 period [5]

The average number of days varies during the year, with the most days with fog occurring in autumn [Figure 2].

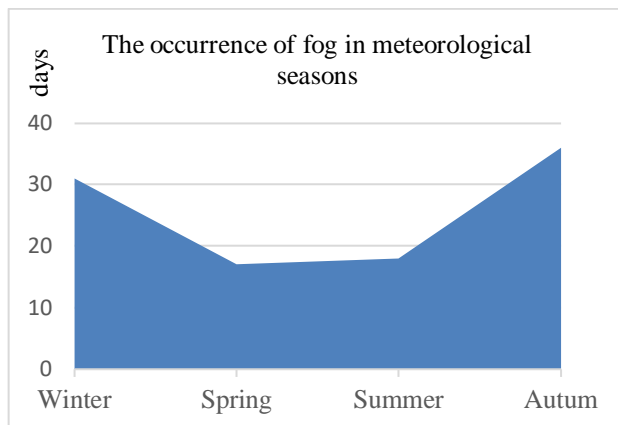


Figure 2 Average number of days with fog during a year at Slovak international airports [5]

More than 1.5 million METAR reports were processed and evaluated in the work [5].

3 What interests us the most?

In meteorology, we are not only interested in the current values of meteorological elements (air temperature, air pressure, wind direction and speed, visibility, phenomena...) but are also interested in the expected development of these phenomena for several days ahead. At present a weather forecast with a relevant warning value can be prepared for a maximum of 3-4 days in advance [1].

Numerous numerical methods are currently used for weather forecasting, which, based on equations and relationships describing events in the atmosphere, can predict the forecast in many places in the globe with a resolution grid of km x km.

We also use information from a wide network of meteorological stations that provide us with information about the course of the weather. This information has different periodicity for different purposes. For example, in aviation meteorology, we use METAR reports - the current state of the weather conditions, or TAF (The Terminal Area Forecast), a forecast for several hours ahead.

In road transport meteorology, it is very important to know not only the state of the atmosphere and possible meteorological phenomena related to it but also the state of the pavement. Here we are served by various sensors built into the pavement, which provide not only up-to-date information about its condition but also serve as an input for pavement condition forecast.

Globally, road transport meteorology is growing importance. There are many papers published on the latest possibilities for dangerous weather phenomena prediction [6-8]. The Standing International Road Weather Commission (SIRWEC) operates as a forum for information exchange on road transport meteorology issues [9]. They include management, road maintenance, road safety, meteorology, environmental protection and other areas of interest considered relevant by the Commission. Historically, SIRWEC holds a conference every two years [9].

SIRWEC's main task is to encourage meteorologists, weather forecasters, highway engineers, road masters and others who are interested in road transport weather problems to exchange ideas to make our road transport safer in all weather conditions [9].

There are also specialised companies focusing on detecting, predicting and evaluating weather conditions on roads in Slovakia. They also expanded their services and experience worldwide. Companies Microstep and/or Spinnet could be mentioned as good examples. Both of those offer a wide range of detection options for dangerous phenomena in various modes of transport. This mainly focuses on air and road temperature, fog and wind data. The changes in these elements in space and time may indicate the emergence of intermediate problems in transport [10,11].

An example of how the typical forecasting system works in a simplified form is shown in Figure 3.

To know the weather conditions status is the prime importance for aviation. Even though the weather forecasts have improved considerably in the last two decades, the weather conditions are one of the major causes of air accidents. Weather conditions deterioration can significantly affect air transport and can cause, for example, delays in large areas. However, not every kind of weather creates dangerous conditions for air transport. Nevertheless, 2018 was very specific, and a record number of adverse weather events and industrial actions that severely disrupted network operations was registered [12-14].

The weather can create weather phenomena that could be dangerous for all traffic modes. Just as the weather changes, so do dangerous weather phenomena adversely affect the regularity, efficiency and safety of any transport modes.

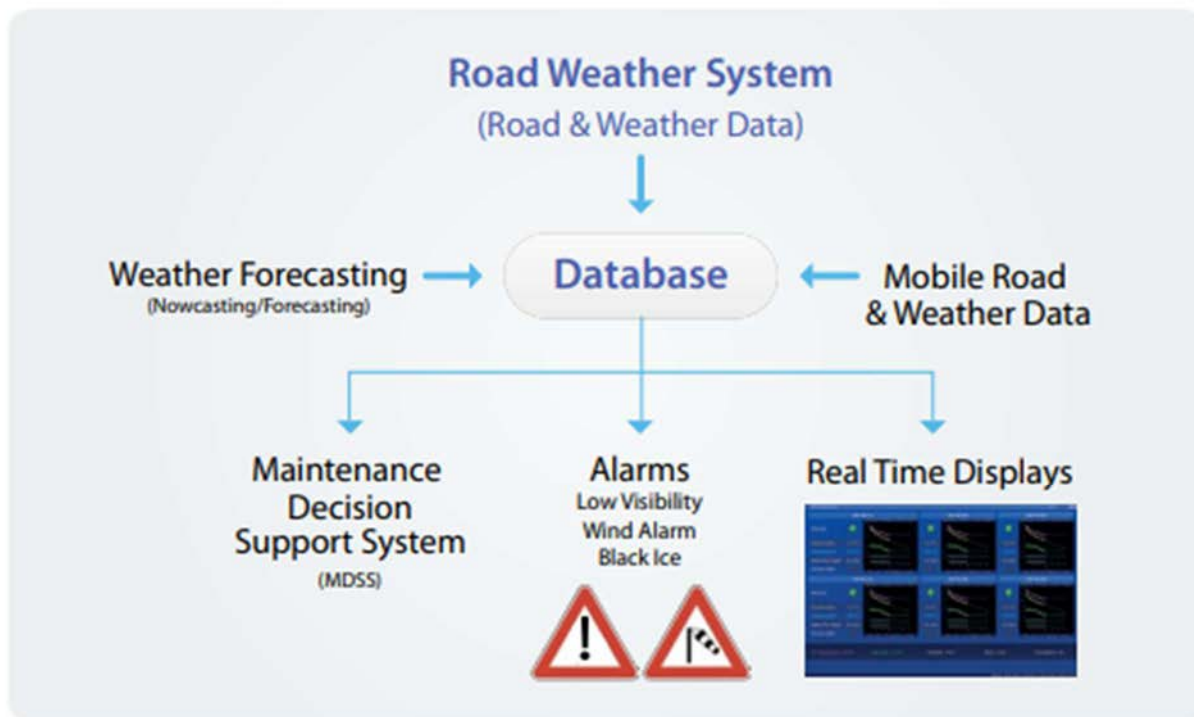


Figure 3 Scheme of road weather registration and prediction system [10]

4 Transport and climate change - new challenges in this industry

As mentioned, the weather and its changes significantly affect our lives and also the transport in small and large areas. In the current period, the problem of climate change is also coming to the fore. Transport is responsible for the amount of greenhouse gases increasing in the atmosphere and intensifying the greenhouse effect.

Global CO₂ emissions from energy combustion and industrial processes rebounded in 2021 to reach their highest-ever annual level. A 6% increase from 2020 pushed emissions to 36.3 gigatonnes (Gt), an estimate based on the IEA's detailed region-by-region and fuel-by-fuel analysis, drawing on the latest official national data and publicly available energy, economic and weather data. The Covid-19 pandemic had far-reaching impacts on energy demand in 2020, reducing global CO₂ emissions by 5.2%. However, the world has experienced an extremely rapid economic recovery since then, driven by unprecedented fiscal and monetary stimulus and a fast - although uneven- roll-out of vaccines. The recovery of energy demand in 2021 was compounded by adverse weather and energy market conditions, which led to more coal being burnt despite renewable power generation registering its largest-ever annual growth. Emissions increased by almost 2.1 Gt from 2020 levels. This puts 2021 above 2010 as the largest ever year-on-year increase in energy-related CO₂ emissions in absolute terms. The

rebound in 2021 more than reversed the pandemic-induced decline in emissions of 1.9 Gt experienced in 2020. CO₂ emissions in 2021 rose to around 180 megatonnes (Mt) above the pandemic level of 2019. The 6% increase in CO₂ emissions in 2021 was in line with the jump in global economic output of 5.9%. This marks the strongest coupling of CO₂ emission with Gross domestic product (GDP) growth since 2010 when global emissions rebounded by 6.1% while economic output grew by 5.1% as the world emerged from the Global Financial Crisis.

Transport was responsible for 30% of global final energy demand and for 23% of global direct CO₂ emissions from the energy sector that year [15].

5 Conclusion – meteorology in transport in the future

Meteorology remains an important partner for improving the quality and efficiency of all types of transport. Meteorological information, very detailed and accurate, helps with planning transport around the world. In addition to traditional meteorological tools, which are well known and used (radar, satellites, models...), AI and its help in solving problems in transport are also coming to the fore.

Transport is of prime importance for most of business and is an indispensable part of our life. However, the aim

of greenhouse gas emissions reduction had to be one of the major aims for transport today.

In many modes of transport, ways are being sought to reduce the impact of transport on the amount of greenhouse gases in the atmosphere. Experiments are being done in the use of green types of energy to drive cars, ships and even aeroplanes.

If we assume that a warmer atmosphere can absorb more water vapour, more water vapour can produce more convective clouds, and more dangerous phenomena can occur from it (heavy showers, storms), it is important to pay more attention to observation, prediction and warning. Meteorology and transport must work very closely together in this respect.

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Review process

Single-blind peer review process.

Management of the grain supply chain during the conflict period: case study Ukraine

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Keywords: transportation services, technology, regression model.

Abstract: The paper highlights the main aspects of designing safety supply chains for grain cargoes and other agricultural commodity delivery. The study's relevance is caused by the fact that periodic port blockades do not allow Ukraine to carry out reliable exports of agricultural products along classical routes. Therefore, there was a need to find new alternatives for exporting agricultural commodities, primarily grain. The study aims to substantiate, describe, structure, and mathematically formalize proposed delivery options and choose the best. The research justifies picking supply chains using automobile and railway transport from Ukraine to the European Union countries. According to three proposed technologies, grain cargoes are exported in batches using containers. The advisability is justified for using each considered delivery option regarding technological aspects. Mathematical modeling, particularly regression analysis, is used to design supply chains. In this case, selecting the best technology is confirmed by corresponding calculations according to designed regression models. The presented option for supplying agricultural commodities is the safest and most reliable but more expensive. However, such logistics will be an excellent solution to reduce the negative consequences of a possible food crisis for the global economy.

1 Introduction

The proposed national transport strategy of Ukraine significantly determines the priority areas for achieving quality transport services during the military conflict. This conception also provides for approaching levels of their support and development of transport infrastructure to advanced European standards. During a period of significant uncertainty in transport support, resolving problems is reducing influences of random factors by building intelligent transport systems. It is demonstrated using smart methods (fuzzy patterns) when predicting trip and delivery time [1].

It is also crucial to improve the level of delivery safety and reduce the negative impact of transport on the environment [2]. It is necessary to respond to funds that improve management systems, implement certain administrative reforms, and qualitatively decentralize tasks and functions for central departments relating to local executive power. It will make it possible to design a high-quality technology for supplying grain cargo in containers

by Ukraine-Europe routes. A good example is supply chain structures using E-commerce platforms [3]. Digitalization during product or cargo flow control allows manufacturers and transport companies to have a certain level of information support in production and distribution systems. This aspect is particularly important if risks are considered posed by emergencies [4]. Herewith, considered emergencies could worsen the stability of designed food supply chains [5] without enough information support.

In addition to ensuring physical security, an important aspect is the creation of safe financial and economic settlements. It is achieved by using innovative technologies for the traceability of grain delivery quality [6] and using non-standard business criteria for assessing investments in a blockchain-based management information system [7]. Reducing uncertainty factors makes it possible to design a reasonably reliable supply chain [8,9]. It is extremely important in connection with the latest trends.

European partners increasingly note the negative impacts of the current conflict on supply reliability and the food independence of European countries [10]. Experts note a significant price increase and logistics complexity during future distribution [11,12]. Repeatedly, food safety issues were considered at sessions of relevant UN committees. It is evidenced by the adopted resolutions and councils [13]. World Bank representatives [14] and traders selling agricultural products to other world regions are concerned about the situation with supplies from Ukraine [15]. Violating Ukraine's established trade routes with the Asian region also causes some nervousness in the population of Vietnam and other Asian states [16].

All of the above confirms the relevance of presented studies to designing reliable and safe food supply chains in such difficult conditions worldwide.

Ukraine belongs to the leading world producers and exporters of agricultural products, which include sunflower oil, wheat, and barley. Significant nomenclature refers to cereals. However, the Russian invasion suspended perspective transportation routes – through Ukrainian ports on the Black Sea, which processed more than 90% of these exports. The sale of grain is significant for our country because it brings in nearly twenty percent of Ukrainian export earnings. In addition, Ukrainian cereals provide food safety for numerous countries in Europe, Asia, and Africa. The European Commission (EC) has developed and implemented measures to assist in transporting various commodities from Ukraine to make grain cargo export safer [17].

The EC quite qualitatively assessed problem areas in supply chains. Thousands of rail wagons with grain have been detained from the Ukrainian part near frontiers with such countries as Poland and Romania. The average idle

time at the border is nearly 16 days, sometimes a month [18]. The main problem at the same time is the width difference in tracks between the railways of Ukraine and European countries. Therefore, to move across state borders, specialists must either change "bogies with wheels" on railway wagons or transshipment cargoes from Ukrainian vehicles to European ones. However, existing capabilities are not enough with current transportation demands, according to data of EC.

Therefore, European officials turned to companies with a proposal to allocate or find "mobile grain reloaders" on the market. One option is also proposed - to deliver grain cargo directly in universal containers since they can be reloaded faster with appropriate cranes from the railway platforms belonging Ukrainian railway to the European one [19].

Since the beginning of the 2021–2022 marketing year (from July 2021), Ukraine has increased the corresponding volumes of export supplies for grain cargo by more than 30% – to 42.6 million tons [20]. Corn and wheat were the most exported. According to official statistics, Ukraine sold 32.5 million tons of grain abroad (Figure 1) in the 2013–2014 marketing period. In 2017–2018, export sales decreased to 39.4 million tons. But the country sold 50.4 million tons of grain to foreign markets in the next quarter, and 2019–2020 – 57.2 million tons. Export deliveries amounted to 44.9 million tons last time. In particular, Ukraine exported 23.1 million tons of the main grain cargo – corn, 16.6 million tons of wheat, 4.2 million tons of barley, and 18.4 thousand tons of rye. As of February 21, 42.6 million tons of grain cargoes were exported in the 2021–2022 marketing period: more corn - 18.7 million tons, wheat – 17.8 million tons, barley – 5.6 million tons, rye – 160.1 thousand tons [21].

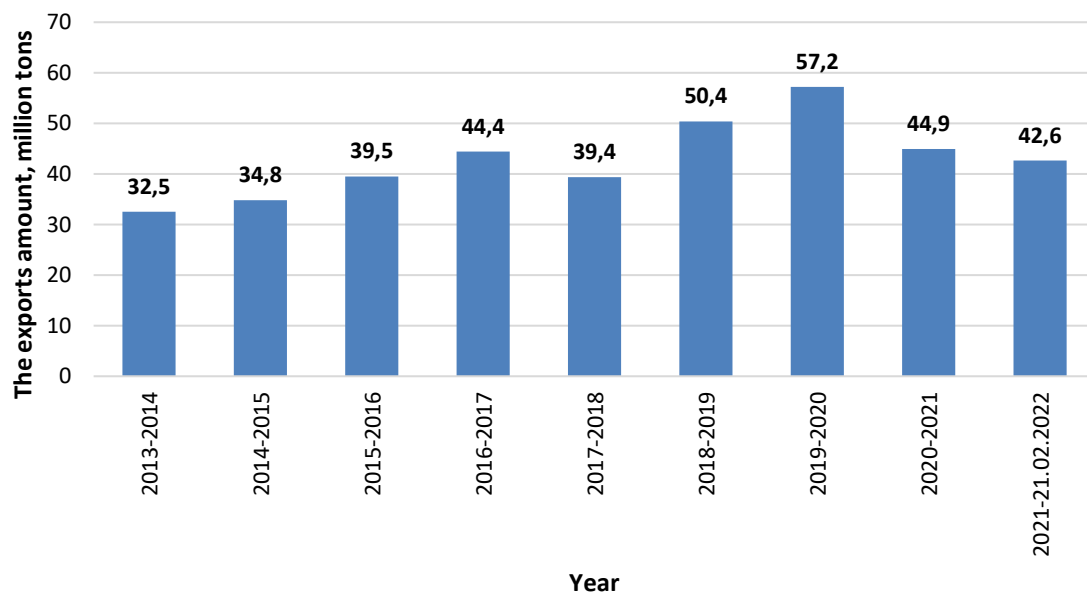


Figure 1 The exports amount of grain and leguminous, and products of their processing in 2013-2021

The grain cargo supply to Europe is a complex technological process where it is necessary to develop multimodal clusters in which production, warehouse, and transshipment capacities will be combined. In the current situation in Ukraine, supply chains using containers for goods delivery are more efficient and reliable but relatively costly. It should make it possible to simplify the process of boundary crossing for railway transportation, precisely with insignificant volumes of orders by rail, but with a considerable distance – for example, when delivered to the Poland or Spain ports [22]. And this aspect is also providing a rational interaction between all elements of supply systems with minimal resource costs. Therefore, it is necessary to choose a methodological approach for designing rational technology grain cargo supplied in containers by Ukraine–Europe routes.

The export of agricultural products from Ukraine is a strategic industry. At the same time, a significant share of products transported by leading international carriers [23] are oilseeds, cereals, and beans. Ukraine exports 91.2% of grain cargo by sea; the rest is by automobile and railway transport. The difficulties associated with changes in the geography of shipments force carriers to look for new, effective solutions. One of these is grain delivered in containers. This transportation kind is characterized by universality, which allows carriers to supply products in small batches with a volume of 500 to 5000 thousand tons. Container transportation allows transport companies to establish contact details with small consumers due to the constant regularity of container international lines, a certain delivery period, and abilities to plan processes clearly.

Grain crops are delivered in bulk by universal containers. This transportation type is characterized by the following advantages: reasonable cost of corresponding freights; shipment can be done in small batches; quotas are not needed for costs of storing grain in elevator warehouses, which are scarce. Transportation of grain cargoes in containers makes it possible to ensure: the transshipment of grain from transport into containers; the possibility of surveying and certification; customs support and clearance; installation of freight, and corresponding booking. At the same time, specialized handling equipment and machines are used for goods transshipment in the company's containers, such as screw reloaders, pneumatic conveyors, etc. [24].

Container exports offer benefits to moving agricultural products through the presence of empty import containers that can be transported, making available domestic "dry ports" more critical in international supply chains. The document [25] highlights the impact and challenges of increasing container transportation for agricultural goods from remote areas to foreign markets in relation to operations and management.

Effective supply tracking is critical to managing global trade and logistics. That's why the organization and management of supply chains are constantly moving

towards cooperation with intellectual and service focus on coping with the growing complexity of customer requirements – this is evidenced according to research by Giustia R. et al. [26]. An important aspect is resource flow control in logistics and other industries: metallurgy [27] and automobile manufacturers [28]. Such principles should be integrated into building supply chains in emergencies based on the classic distribution approaches of food flows [29, 30] and grain cargoes on multimodal routes [31]. Moreover, Ukrainian ports can be closed anytime to export agricultural products [32]. It will lead to searching for alternative supply chains. Therefore, some of the most possible options for multimodal routes using container delivery technology were reasoned and studied in detail in this research.

2 Methodology

The country's logistics potential is a combination of realized and promising opportunities for creating logistics systems and effective management of material and related flows, which make it possible to improve the economic situation per territory and increase its competitiveness [33]. This definition reflects the main characteristic of the country's logistics potential - using opportunities provided by the country to its logistics systems [33].

In the study, to achieve a goal, we will determine alternative technologies for delivering grain cargo in international traffic – Ukraine – Europe, considering the possibilities lack using seaports. The supply uses the road, railway transport, and related terminals. The using containers possibility for transportation will be considered. To define the least costly option, it is proposed to apply mathematical modeling with regression model determination based on selected impact parameters.

Based on information analysis of 10 companies operating in grain cargo logistics, statistical data were obtained on parameters of applications from customers: grain cargo order volume; transportation distance during input (output) cargo flows; transportation distance (mileage) by trunk transport. The selected parameters are considered in the interval view. This study defines a number of conditions: 1) all demand characteristics for senders and recipients of grain cargo are known; 2) the delivery process participants are grain elevators, transport companies (carriers), and railway; 3) the used resources characteristics (containers, railway-wagons, trucks, terminals) are determined; 4) the control system determines service priorities according to product readiness rate; 5) customs authorities take an active part in process control of frontier across.

Consider three alternative technologies for delivering grain cargo in international traffic - Ukraine - Europe, excluding regular delivery through ports.

The first technology is considered from the moment grain trucks unload at elevators, then batches of grain cargo are stored until the moment arriving grain trucks at the elevators (Figure 2). The next logistic operation - cargo

batches are loaded into grain railway wagons. Then, several wagons are sent to sorting railway stations, where completed trains depart to frontier stations. At this station, wheel sets are changed to "European" ones, and

appropriate documents are drawn up with established cargo checks. After that, trains go to European destination stations, where cargo is unloaded and stored. Further, grain trucks supply grain cargo to recipients.

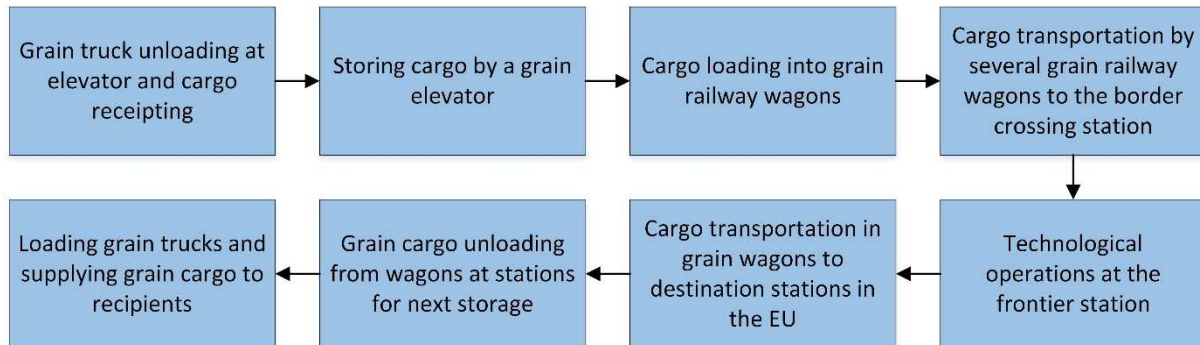


Figure 2 Schematic representation for options of grain cargo delivery along the routes Ukraine - Europe - "Technology 1"

Logistics companies use the second technology for unloading grain trucks moment at elevators. Batches of grain cargo are stored until containers are supplied to loading areas, and then containers are loaded (Figure 3). Further, containers are stored for some time in warehouses (elevators). They are loaded onto mobile railway platforms, and then formed departure of several railway wagons is sent to sorting stations, where a completed train

is heading to frontier stations. At these stations, containers are transferred to platforms of "European" carriers, and appropriate documents are drawn up. Afterward, the trains go to destination stations in the EU, where containers are unloaded and stored. From storage areas, containers are loaded onto special vehicles and transported to consignees, where grain cargoes are unloaded from containers.

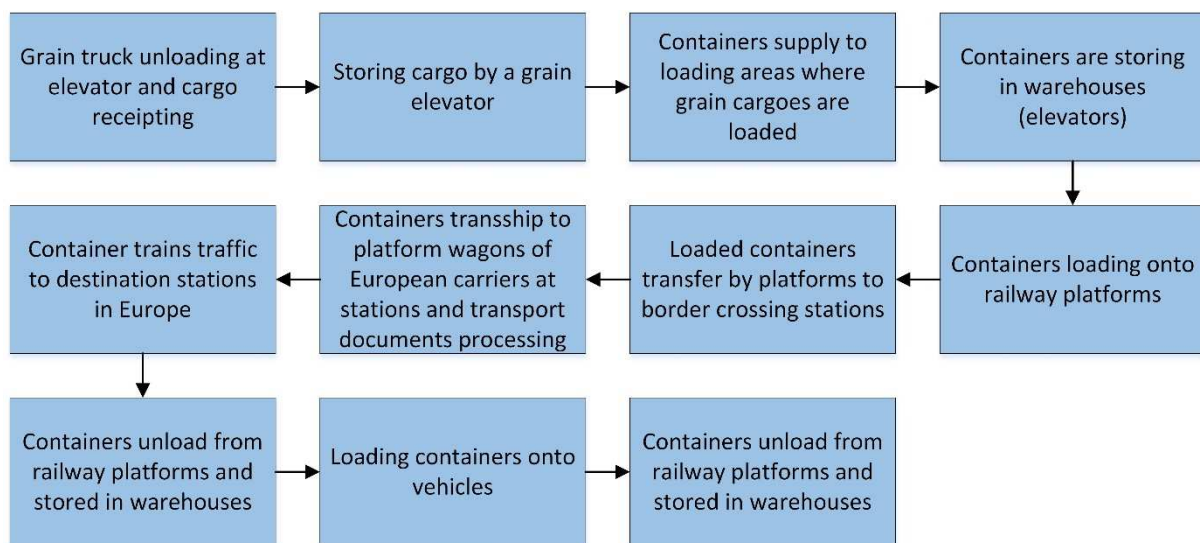


Figure 3 Schematic representation for options of grain cargo delivery by containers along the routes Ukraine - Europe - "Technology 2"

The third technology also begins with grain trucks unloading at elevators. Batches of grain cargo are stored until containers are supplied to loading zones, and containers located on container trucks are loaded with grain cargo (Figure 4). Further, these vehicles go to state borders, crossing frontiers with customs operations passaging. Special trucks with containers follow by European Union

territory. Containers are unloaded from vehicles to warehouses (elevators) in Europe. Then, after storing grain cargo in containers at warehouses, they are transferred from containers to grain trucks based on orders, which then transport cargo to consignees and are unloaded at their recipient points.

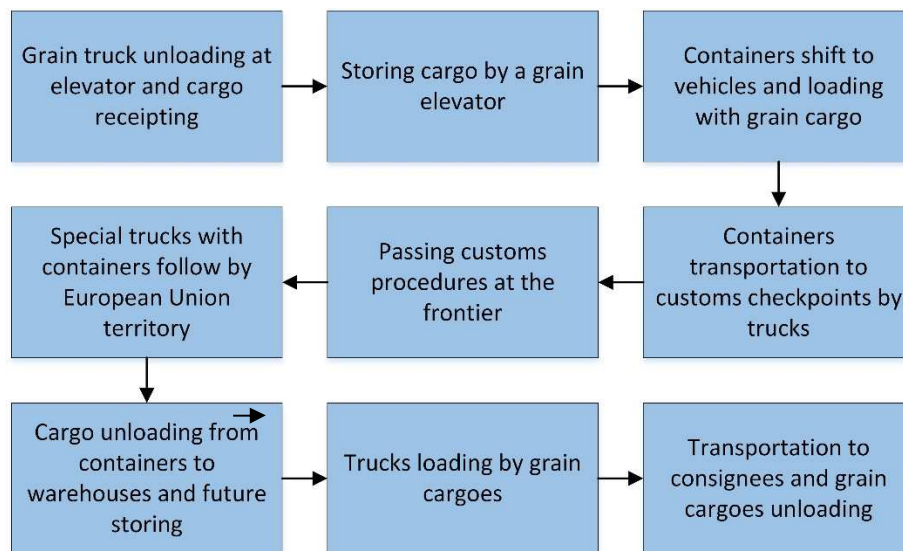


Figure 4 Schematic representation for options of grain cargo delivery by containers along the routes Ukraine - Europe - "Technology 3"

Determination of rational technology of grain cargo delivery in containers is proposed to be carried out according to the estimated indicator - total costs (Z_s), which form values set off a certain i th type of cost for each considered element of the technology

$$Z_s = \sum_{i=1}^n Z_i, \forall n = 1, \dots, 8. \quad (1)$$

The following parameters influence the estimated indicator: grain cargo order volume (Q_R); transportation distance during input (output) cargo flows (L_d); transportation distance (mileage) by trunk transport (L_m); time parameters of operations execution (t_{oe}); performed operation cost (S_{oc}).

To achieve the proposed goals of research, a mathematical model has been designed for rational technology determining during grain cargo delivery, which takes into account: the container loading (unloading) costs ($Z_{u(l)}^{cont}$); costs for loading (unloading) and reloading of grain cargo (container) to (from) a vehicle (truck, wagon) of corresponding transport types ($Z_{u(l)}^{vec}$); costs of grain cargo (container) storage in the warehouse and technological idle time for corresponding transport (Z_{st}^c); transportation costs of grain cargo (container) by vehicle type (truck, wagon) in the corresponding transport kind in Ukraine and Europe (Z_{tr}); waiting for costs for grain cargo (container) shipment by corresponding kinds of trunk transport (Z_{exp}^{tr}); document processing costs for grain cargo (container) delivery (Z_d^{cl})

$$Z_s = Z_{u(l)}^{cont} + Z_{u(l)}^{vec} + Z_{st}^c + Z_{tr} + Z_{exp}^{tr} + Z_d^{cl}. \quad (2)$$

The container loading (unloading) costs are taken into account: container loading (unloading) average cost with

grain cargo ($C_{u(l)}^{cont}$); loading (unloading) time of grain cargo in (from) containers per one ton ($t_{u(l)}^{cont}$)

$$Z_{u(l)}^{cont} = C_{u(l)}^{cont} \cdot t_{u(l)}^{cont} \cdot Q_R, \forall Q_R = \{20; 280\}. \quad (3)$$

The costs of loading (unloading) and reloading of grain cargo (container) to (from) a vehicle (truck, wagon) of the corresponding transport kind shall be taken into account: average cost of loading (unloading), reloading to corresponding transport kind (i) at a certain point (j) (container storage warehouse, railway sorting station) ($C_{u(l)ij}^c$); loading (unloading), reloading of corresponding cargo (container) quantity ($t_{u(l)ij}^c$); limit quantities of transport kinds (k); quantity limit of cargo transships points according to corresponding delivery schemes (f); quantity of cargo (containers) loaded (unloaded) on (from) corresponding kind transport at a certain point (n_{contij})

$$Z_{u(l)}^{vec} = \sum_{i=1}^k \sum_{j=1}^f C_{u(l)ij}^c \cdot t_{u(l)ij}^c \cdot n_{contij}, \forall k = \{1; 2\}; f = \{1; 20\}. \quad (4)$$

The costs of storing grain cargo (container) at warehouses and technological idle time at corresponding transport kinds must take into account: average cost of storing grain cargo and technological idle time at the corresponding transport kinds at a certain point (warehouse, sorting railway station) (C_{stij}^c); time for storage of appropriate cargo (container) quantities and technological idle time using appropriate transport kind at a specific cargo transship point (t_{stij}^c)

$$Z_{st}^c = \sum_{i=1}^k \sum_{j=1}^f C_{stij}^c \cdot t_{stij}^c \cdot Q_R, \forall k = \{1; 2\}; f = \{1; 20\}. \quad (5)$$

The costs of transporting grain cargo (container) by a vehicle (truck, wagon) belonging to corresponding transport kinds in Ukraine and Europe are taken into account: transporting grain cargo (container) average cost by corresponding transport kinds on a specific chain ($C_{tr.ir}$); cargo tranship points quantity limit according to the corresponding delivery scheme (w); corresponding transportation distances (input (output) cargo flow for long distance) of grain cargo (container) by connected transport kind in a specific chain ($L_{tr.ir}^{d,m}$)

$$Z_{tr} = \sum_{i=1}^k \sum_{r=1}^w C_{tr.ir} \cdot L_{tr.ir}^{d,m}, \forall k = \{1, 2\}; w = \{1, 4\}; L_{tr.ir}^{d,m} \in L_d \cup L_m. \quad (6)$$

Awaited shipment costs for grain cargo (container) using corresponding trunk transport kinds shall be taken into account: awaited shipment average cost for grain cargo (container) using corresponding trunk transport kinds at a specific cargo transship point ($C_{exp.ij}$); waiting time for shipment of grain cargo (container) using the corresponding transport type at a certain point ($t_{exp.ij}^{tr}$); impact-factor influence on idle time using corresponding transport kinds at a certain point ($K_{inf.ij}$)

$$Z_{exp}^{tr} = \sum_{i=1}^k \sum_{j=1}^f C_{exp.ij} \cdot t_{exp.ij}^{tr} \cdot Q_R \cdot K_{inf.ij}, \forall k = \{1, 2\}; f = \{1, 20\}; K_{inf.ij} = \{1.1; 1.5\}. \quad (7)$$

The document processing costs of grain cargo (container) delivery are taken into account: issuing documents costs for cargo delivery by a certain transport kind ($C_{d.i}$); insurance costs for goods supplied by a certain transport kind ($C_{ins.i}$); customs clearance cost per vehicle (C_{cost}^{tr}); customs clearance cost of grain cargo (C_{cost}^c)

$$Z_d^{cl} = \sum_{i=1}^k (C_{d.i} + C_{ins.i}) \cdot n_{cost} + C_{cost}^{tr} + C_{cost}^c, \forall k = \{1, 2\}. \quad (8)$$

First, to solve problems using the proposed methodology, it is necessary to carry out a statistical data assessment from 10 companies operating in the Ukrainian market. Order flows for 2021 are used as input data because the current situation doesn't give any opportunity to receive alternative information about recent amounts of transportation. The variables are the following flow characteristics: amounts of grain cargo order, transportation distance during input (output) cargo flow, and transportation distance by trunk transport. The values were obtained by analyzing orders for grain goods delivery from Ukraine to the European Union, and the total number of orders (observations) equals one hundred.

3 Result and discussion

To obtain the most reliable data about value changes of technological parameters describing processes of container delivery on certain supply chains, the required observations sample is determined (Table 1).

Table 1 Main mathematical characteristics of supply chains

Parameter	Grain cargo order amount (t)	Transportation mileage during input (output) cargo flow (km)	Transportation mileage due to long-distance supply (km)
Expected value	150	40	1553.5
Standard deviation	126.80	56.05	438.05
Measurement error	7.50	2.00	77.68
Sample size	92	97	55

The correlation between the two variables was estimated by Chi-square. When using Statistica software, calculations were made to determine the distribution laws for parameters of input order flows. It has been established that their values are distributed according to the normal distribution of random variables. Three factors were

established influencing estimated indicators, and minimum and maximum values were determined using formulas (2-8). The last was found by evaluating selected values from three parameters (Table 2). Based on these data, an experimental plan was completed according to obtained statistics (Table 3).

Table 2 Exposure factor variation levels

Value levels	Grain cargo order amount (t)	Transportation mileage during input (output) cargo flow (km)	Transportation mileage due to long-distance supply (km)
Minimal	20	15	312
Maximal	280	65	2795

Table 3 Levels of influence factor variation (actual values)

Observation series	Variation levels		
	Grain cargo order amount (t)	Transportation mileage during input (output) cargo flow (km)	Transportation mileage due to long-distance supply (km)
Test 1	20	15	312
Test 2	20	15	2795
Test 3	20	65	312
Test 4	280	15	2795
Test 5	280	15	312
Test 6	280	65	312
Test 7	20	65	2795
Test 8	280	65	2795

Regression analysis was performed by two function types: linear and power. Microsoft Excel software was used to design proposed model types, using a built-in program for calculating regression. In this study, regression analysis was performed using established function types for each technology. It is determined that the linear function will be best according to mathematical

analysis since the criteria value "R-square" is maximum and equal to 1 (for all three cases). Evaluation parameter values checked the value of the corresponding coefficient for the linear type regression model. They are adequate, except for the free member of the second model. This indicator is not considered when designing the linear model "Technology 2" (Table 4).

Table 4 Regression models for each supply chain option

Supply chain option	Regression model
"Technology 1"	$Z_{s1} = 500 + 511.44 \cdot Q_R + 45 \cdot L_d + 27.5 \cdot L_m$
"Technology 2"	$Z_{s2} = 493.77 \cdot Q_R + 42 \cdot L_d + 18 \cdot L_m$
"Technology 3"	$Z_{s3} = 1000 + 310.7 \cdot Q_R + 45 \cdot L_d + 37.8 \cdot L_m$

The obtained regression models were used to calculate choosing criteria for rational grain cargo delivery

technologies (Figure 5). Thus, input data are used as maximal and minimal input order flow parameter values.

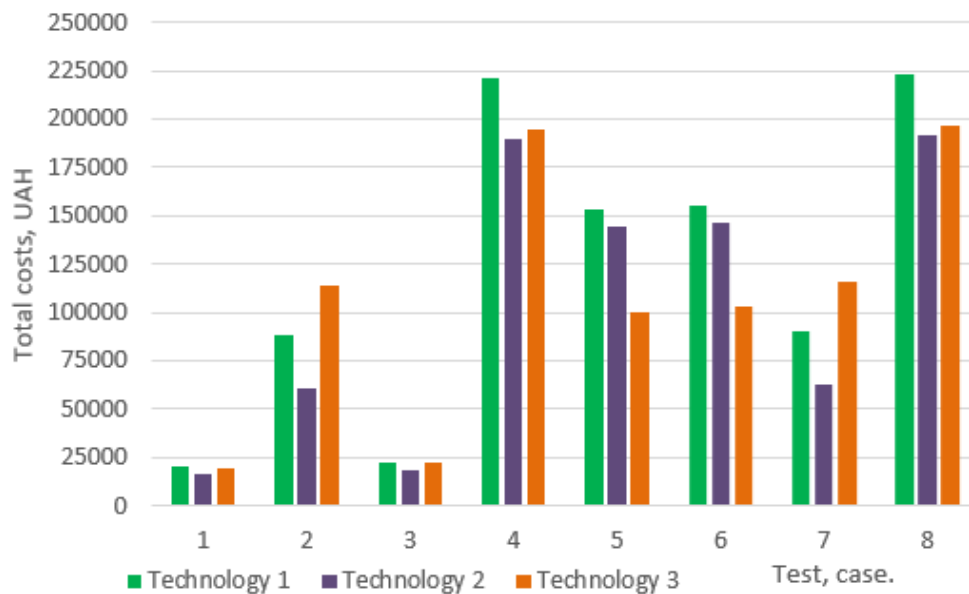


Figure 5 Dependence diagram of total costs for grain cargo delivery in containers on routes from Ukraine to Europe from values combinations of corresponding input parameters for each experiment test

Costs were compared for each technology. It helped to determine more economical options for effect according to combinations of influence parameter values (Table 5). The

second technology (transportation of grain cargo in containers by long-distance rail transport) is less expensive than Technology 1 (transportation of grain cargo in grain

wagons by long-distance rail transport), with all combinations of influence parameter values, with the greatest effect being 32195.10 UAH. The greatest effect with all possible combinations of comparison is 52874.60

UAH. It is possible when using "Technology 2" compared to "Technology 3" (transportation of grain cargo in containers by trucks) at maximum distances and minimum volume of grain cargo order.

Table 5 Results of economic effect comparing

Observation series	Effect (UAH)		
	Comparing results for "Technology 1" and "Technology 2"	Comparing results for "Technology 1" and "Technology 3"	Comparing results for "Technology 2" and "Technology 3"
Test 1	3862.40	301.20	-3561.20
Test 2	27450.90	-25273.70	-52724.60
Test 3	4012.40	301.20	-3711.20
Test 4	32045.10	26918.70	-5126.40
Test 5	8456.60	52493.60	44037.00
Test 6	8606.60	52493.60	43887.00
Test 7	27600.90	-25273.70	-52874.60
Test 8	32195.10	26918.70	-5276.40

4 Conclusions

This research represents the results of conditions determining under which carriers (grain traders, supply companies) can choose a rational version of the technology for delivering grain cargo using containers by Ukraine-Europe routes. For this, a methodology was developed that included the following elements: alternative options design for technologies of grain cargo supplying; parameters definition for selection evaluating of an effective variant; creating mathematical models for values determining estimated parameters; modeling and evaluating results.

It was proposed to consider this process using three options of their organization with the participation of automobile, railway transport, and corresponding terminals to determine the rational option of grain cargo delivery by containers. Data from 10 companies to form these schemes that organize grain cargoes and containers delivering from Ukraine to Europe were used. The designed options consider the possibilities of using elevators and container areas on Ukrainian territory for storing grain cargo.

Mathematical modeling was the most promising approach for correctly describing the specifics of supplying grain cargo in containers. This nuance improves understanding of the complexity of cause-and-effect logical relations corresponding to certain supply chains. That's why, as a parameter for selecting an effective grain cargo supply chain in containers, the total costs for the delivery of grain cargo were selected considering the restrictions.

A full-factor experimental plan was developed for the three selected parameters, consisting of eight series experiments. At the same time, various combinations of external impact parameters were used, such as grain cargo order volume; transportation distance during input (output) flows; transportation distance by main multimodal kind of transport. Regression analysis was performed by functions of two types: linear and power. It was found that the linear

function model is most adequate because the "R-square" value is equal to one.

Regression models of the corresponding type were built for three options for delivering grain cargo in containers on routes from Ukraine to Europe. The effect-determining results showed that "Technology 2" when compared with "Technology 1" at all combinations of values of technological parameters, will have a positive result – the total costs are less (the highest effect level is 32195.10 UAH at maximum values of input parameters).

Future studies will explore other opportunities for designing grain and food supply chains using river routes that will be compared with the models created and obtained results of the current investigation. Such perspectives allow logistics companies to offer alternative supply chain options depending on priority terms specified in requisitions. It improves responsiveness to fluctuations in demand and resource optimization used in the process by all participants in supply chains.

Acknowledgment

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Current state and improvement prospects of warehouse workers health and safety practices in Bulgarian manufacturing and trading organizations

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Abstract: Occupational health and safety (OHS) of warehouse workers is a crucial issue for warehouse managers. The importance of OHS practices has increased over recent years due both to high levels of fatal accidents in the logistics industry, and chronic shortage of labor in the sector, which requires systematic efforts to reduce absenteeism and increase warehouse employee motivation. This article aims to address the current state of some fundamental OHS practices of warehouse workers in Bulgarian manufacturing and trading organizations, and to outline some recommendations for their future improvements. The data were collected using the questionnaire survey method among 91 manufacturing and trading organizations in Bulgaria, which operate warehouses, and were processed using Chi-square analysis. The results show that the share of trading organizations, which implement OHS practices is lower, in comparison with surveyed manufacturing organizations. In addition, small organizations lag behind medium and large regarding the use of fundamental measures to protect warehouse workers. The main research findings indicate that there is a need to expand the frequency of OHS practices applied in trading organizations through a wider implementation of joint firefighting drills with fire and emergency safety authorities, adaptation of warehouse infrastructure, clear designation of emergency exits and placement of signs/work instructions for safe work at workplaces. Furthermore, it is critical to increase the use of appropriate work clothing and personal protective equipment (PPE), as well as to provide regular safety briefings in trading warehouses and small organizations.

1 Introduction

OHS practices are an issue of increasing importance for warehouse managers. According to data provided by Eurostat in 2019 the transport and storage sector ranks second, and accounts for 15% of all fatal accidents at work in the EU-27 countries [1]. The operations carried out in the warehouse engage a significant human resource in labor-intensive activities that are performed in a working environment with a high degree of risk and hazards. In addition, physical work in the warehouse leads to fatigue and causes stress arising from the increasing demand to cut down on customer service time. All that has an adverse effect on the attractiveness of the logistics industry. As a result, in recent years the logistics sector has been known to suffer from a chronic labor shortage [2], including warehouse operations. In these conditions, ensuring adequate practices for health and safety working conditions of warehouse workers becomes a crucial issue for warehouse managers. On the one hand, they look for options to reduce accidents resulting in inefficient use of the available workforce. On the other hand, improving the working conditions in the warehouse is an important prerequisite in efforts to boost the motivation of warehouse workers.

Despite the growing number of publications dealing with various aspects of OHS practices in general, little is known at this point about their application in terms of warehouse workers in manufacturing and trading organizations both in Bulgaria and abroad. The importance of this issue for manufacturing and trading organizations

stems from three main factors. First, in 2019 about a third (31%) of non-fatal accidents at work resulting in at least 4 days of absence and about a quarter (22.9%) of fatal incidents occurred in the manufacturing and trading sector in the EU-27 [1]. Second, the incidents often happen in warehouses during the movements of material flows by forklifts [3], which are used there due to their universal application in heavy loads handling [4]. Third, previous research in the manufacturing industry has been focused on studying the relationship between OHSAS 18001 certification and operating performance [5], revealing the results of the implementation of a complex safety program in an automotive parts plant [6], outlining the issues of safety requirements provided by service providers in the automotive industry [7], analyzing the factors for building a safe work culture in the Malaysian manufacturing industry [8], the safety of the work environment in Korean manufacturing [9], as well as the relationships between work accidents and the causes of their occurrence in Romanian organizations [10], including manufacturing and trading, but has failed to reveal the most commonly applied practices for health and safety working conditions of warehouse workers.

Occupational accidents in Bulgaria are a serious challenge. In 2019, the country ranked second in the EU-27 with 3.37 fatal occupational accidents per 100 000 employees [1], which is 2 times higher than the average level for the EU member states. Nevertheless, OHS practices in the logistics sector have not been included in the scope of some of the most significant studies in this

field [11,12]. Therefore, it is the right moment now to study the OHS practices in manufacturing and trading organizations, and Bulgaria is the right place to conduct such kind of research. Previous studies found insufficient knowledge in this field [13], as well as the need to apply an interdisciplinary research approach when conducting studies [14]. In addition, workers in small and medium-sized organizations are among the most at risk of injuries at work [15]. This shows that the size of the organization can also influence OHS practices. Currently, this relationship is inadequately examined and hence it is also worth researching.

Therefore, the aim of this article is to reveal the current state of some basic OHS practices of warehouse workers in Bulgarian manufacturing and trading organizations based on which to outline the necessity for their future improvement. To achieve this goal, the following research questions need to be clarified:

1. *What are the fundamental and most frequently used OHS practices of warehouse workers?*

2. *Are there statistically significant relationships between OHS practices of warehouse workers and organization type/ organization size?*

3. *What is the strength of the relationships between the variables mentioned?*

4. *What are the individual differences in the statistically significant relationships between the variables?*

5. *What recommendations for improving the health and safety practices of warehouse workers can be formulated and addressed to stakeholders?*

This study extends existing knowledge on the application of OHS practices in two ways. First, it outlines the importance of the practices most commonly applied for the protection of warehouse workers in the high-risk sectors of manufacturing and trading in Bulgaria, for which the currently available knowledge is still insufficient. Second, the research provides some practical guidelines to assist warehouse managers in their efforts to improve the working environment and working conditions and to support policy makers in building a more favourable regulatory environment and funding opportunities for organizations to enhance health and safety culture in warehouses.

The results of this article will offer valuable initial scientific and practical inferences not only in the Bulgarian context, but also for other developing countries lacking knowledge of OHS practices involving warehouse workers.

The rest of this article is organized as follows. The theoretical framework of the study is presented in section 2. Section 3 deals with data and methods used. The results of the study are addressed in Section 4. Section 5 focuses on the discussions about OHS practices as well as some recommendations to warehouse managers and policy makers. Concluding remarks and some guidelines for future research are provided in Section 6.

2 Theoretical framework

OHS of warehouse workers is a controversial management area that requires the achievement of a number of compromise solutions. On the one hand, the improvement of working conditions promotes a better labor force utilization by reducing sick leaves and increasing work capacity. It also helps decrease the compensation costs for occupational accidents, and the losses caused by damage to warehouse equipment, involved in accidents with warehouse workers. On the other hand, however, ensuring OHS requires financing a number of measures to improve the working environment, which reduces the profit margin. All this requires warehouse managers to be precise when opting for the set of OHS practices applied.

A number of good practices for OHS ensuring of warehouse workers are found in specialized books, standards and some scientific studies. This study identifies some basic and frequently applied practices that will support efforts of logistics managers to build both a better working environment, and better working conditions in warehouses. These practices are systematized in three groups.

The first group comprises the conduct of general and specialized OHS training. Conducting general training [16-19] stems from employers' commitments to provide their workers with a basic understanding of all aspects related to OHS. In addition, training in narrowly defined fields also contributes significantly to reducing accidents with warehouse workers. Some basic OHS practices applied in these fields involve: first aid training [18-21]; demonstrations of available equipment safety use [18,21]; joint firefighting drills with fire and emergency safety authorities [16,18,21], as well as periodical evacuations of warehouse workers and visitors [20,21].

The second group covers various OHS practices that will mitigate warehouse workers' risks arising from working environment. Measures such as adaptation of warehouse infrastructure [16-18,20] by improving the lighting of work areas, better protection of pedestrian walkways, etc.; use of equipment for protective signals [20,22]; clear designation of emergency exits [16,18,19]; designation of places with first aid kits [17,18,20] and placement of signs/work instructions for safe work at workplaces [18,21] are of top priority when ensuring safer working conditions.

The third group of OHS practices takes into account the efforts of employers to improve working conditions. Fundamental measures of key importance in this field are related both to provision of appropriate work clothing and PPE [16-19,21], and periodically conducting safety briefings [21].

3 Data and methods

3.1 Data

The article presents the final results of a survey conducted among manufacturing and trading organizations in Bulgaria that use warehouses.

The data were collected using the questionnaire survey method during the period April – May 2020. The survey was conducted online through the LimeSurvey platform. The questionnaire used consisted of a general and a specialized section, the latter containing OHS practices issues. The general questionnaire section was completed by 134 organizations, and the specialized section with OHS practices by 91 organizations or about 68% of those participating in the survey. The share of manufacturing organizations was 40.70% and that of trading organizations was 59.30%. In terms of size, 44% of the organizations were small (up to 49 employees), 31.85% were medium-sized (from 50 to 249 employees) and 24.15% were large (more than 250 employees). Only representatives of organizations familiar with OHS practices in use took part in the survey. They were selected among the other participants through a control question for access to the specialized section.

The questionnaire used for the survey was approbated during the period February – March 2020.

Data processing in the present study was performed using SPSS, ver. 20 and MS Excel software.

3.2 Methods

To clarify the research questions posed in the present study a five-stage research approach that engaged various research methods was applied.

Within the first stage, based on a literature review with the help of content analysis, some of the most significant practices for ensuring health and safety of warehouse workers were identified. They were included in the test version of the questionnaire. It was approbated with ten participants including seven warehouse managers with up to 5 years of relevant experience, as well as two warehouse managers and a consultant with more than 5 years of experience in the field. The results of the approbation verified the identified OHS practices of warehouse workers as some of the most frequently used, and they were incorporated in the final version of the questionnaire. Therefore, in the construct "implemented practices to ensure OHS of warehouse workers" the following measurement items were included: general training on health and safety at work; first aid training; demonstrations of available equipment safety use; joint firefighting drills with fire and emergency safety authorities; conducting periodical evacuations of warehouse workers and visitors; adaptation of warehouse infrastructure; use of equipment for protective signals; clear designation of emergency exits; designation of places with first aid kits; placement of signs/work instructions for safe work at workplaces; provision of appropriate work clothing and PPE, as well as periodically conducting safety briefings.

During the second stage, a reliability evaluation of the measurement items in the used construct was carried out using the Cronbach's alpha coefficient – Table 1.

Table 1 Construct, measurement items and Cronbach's alpha coefficient, used to study of warehouse workers' OHS practices in Bulgarian trading and manufacturing organizations

Construct	Measurement items	Cronbach's alpha coefficient value
Implemented practices to ensure OHS of warehouse workers	1. General training on health and safety at work	0.828
	2. First aid training	
	3. Demonstrations of available equipment safety use	
	4. Joint firefighting drills with fire and emergency safety authorities	
	5. Conducting periodical evacuations of warehouse workers and visitors	
	6. Adaptation of warehouse infrastructure	
	7. Use of equipment for protective signals	
	8. Clear designation of emergency exits	
	9. Designation of places with first aid kits	
	10. Placement of signs/work instructions for safe work at workplaces	
	11. Provision of appropriate work clothing and PPE	
	12. Periodically conducting safety briefings	

Source: author's calculation

The result obtained shows good reliability ($\alpha = 0.828$). This means that the selected measurement items can be used for subsequent statistical analyses.

To establish the statistical significance of warehouse workers' OHS practices in terms of both organization type and organization size, statistical hypotheses testing using Chi-squared analysis was performed. It was chosen

because qualitative variables such as type of organization, size of the organization, as well as implemented OHS practices were used.

The requirement of no cells with minimum theoretical frequencies below 5 in regard to the relationship between conducting of general training on health and safety at work and organization size wasn't met. In the subsequent

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analysis this relation wasn't analyzed, because inferences drawn would be of compromised credibility. The analysis of the rest relationships shows that all the reliability requirements of the Chi-square analysis in terms of theoretical frequencies and sample size were met. Consequently, the results can be interpreted.

Within the third stage, for the statistically significant relationships established between the variables, the strength of the relationship was evaluated. For this purpose, the Cramer's coefficient was used.

During the fourth stage, the individual differences in the shares of OHS practices applied both for organization types and for organizations by size were assessed with the help of descriptive statistics toolkit. Only the differences

referring to the established statistically significant interrelationships were discussed.

Within the final stage, on the basis of the results obtained for the state of OHS practices in Bulgarian manufacturing and trading organizations, some recommendations for their improvement addressed to warehouse managers and policy makers were provided.

4 Results

In this section, the results of the applied statistical tools are presented and analyzed. Table 2 shows relationship between OHS practices applied and research variables for which all the reliability requirements of the Chi-square analysis are met.

Table 2 Results of Pearson Chi-Square tests for the relationship between OHS practices applied and organization type/organization size

OHS practices	Statistically significant relationship between practices applied and organization	
	type	size
1. General training on health and safety at work	0.1476	-
2. First aid training	0.2584	0.0982
3. Demonstrations of available equipment safety use	0.3980	0.2964
4. Joint firefighting drills with fire and emergency safety authorities	0.0164*	0.1432
5. Conducting periodical evacuations of warehouse workers and visitors	0.0908	0.3995
6. Adaptation of warehouse infrastructure	0.0145*	0.4715
7. Use of equipment for protective signals	0.1133	0.4512
8. Clear designation of emergency exits	0.0069*	0.0780
9. Designation of places with first aid kits	0.0523	0.4334
10. Placement of signs/work instructions for safe work at workplaces	0.0167*	0.3281
11. Provision of appropriate work clothing and PPE	0.0009*	0.0012*
12. Periodically conducting safety briefings	0.0499*	0.0190*

Asymptotic Significance (1-sided); * Statistical significance, $p < 0,05$

Source: author's calculation

The analysis of significance levels shows that there are several statistically significant relationships between the OHS studied practices in the warehouses of the Bulgarian manufacturing and trading organizations and the variables

organization type and organization' size. The statistically significant relationships established are evaluated by the Cramer's coefficient, and the results are systematized in Table 3.

Table 3 Results of Cramer's coefficients for the established statistically significant relationships between OHS practices applied and organization type/ organization size

OHS practices	Statistically significant relationship between the practices applied and organization			
	type		size	
	Cramer's coefficient value	Relationship strength	Cramer's coefficient value	Relationship strength
Joint firefighting drills with fire and emergency safety authorities	0.224	weak	-	-
Adaptation of warehouse infrastructure	0.229	weak	-	-
Clear designation of emergency exits	0.258	weak	-	-
Placement of signs/work instructions for safe work at workplaces	0.223	weak	-	-
Provision of appropriate work clothing and PPE	0.326	average	0.365	average
Periodically conducting safety briefings	0.173	weak	0.268	weak

Source: author's calculation

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The analysis of the Cramer's coefficients shows that for the statistically significant relationships established between research variables, weak strength of relationships prevails. An exception with regard to the practice related to provision of appropriate work clothing and PPE is observed. For this OHS practice applied, medium relationship strength is established both with respect to organization type and organization size.

The existence of relationships, despite predominantly weak strength, indicates that individual differences in the meanings of OHS practices for the research variables can be interpreted. These differences, in terms of OHS practices applied and organization type are presented in Figure 1.

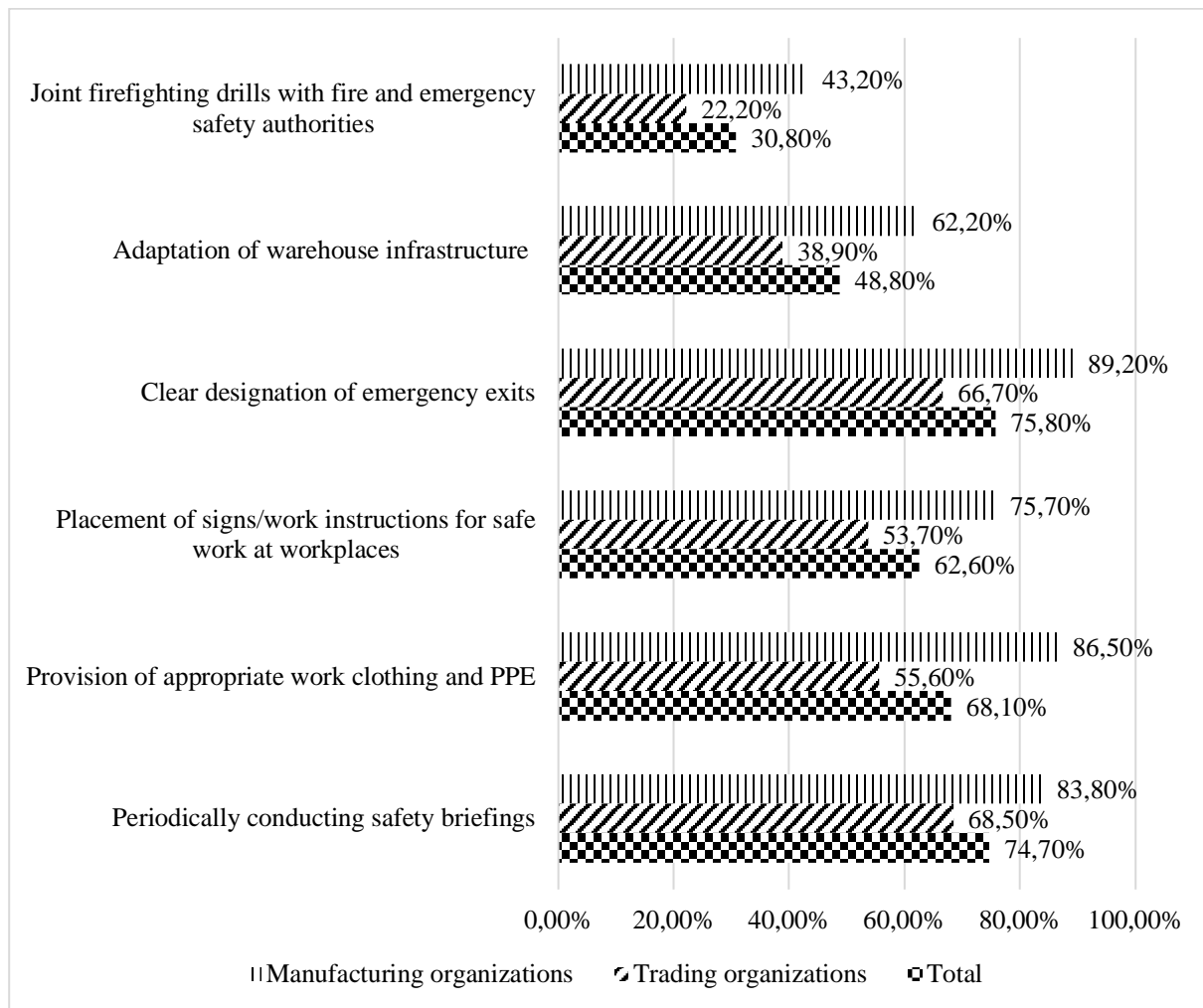


Figure 1 OHS practices applied in Bulgarian manufacturing and trading organizations - overall and by organization type
Source: author's calculation

The analysis of the data shows that OHS practices of warehouse workers are applied to a greater extent in manufacturing organizations compared to trading ones. In manufacturing warehouses, there are more health and safety risks for warehouse workers due to the proximity of production machinery and the greater frequency of handling operations with heavier and bulkier loads. In addition, manufacturing organizations more often have occupational health and safety experts who contribute to integrated improvement of health and safety measures in all organizational entities.

Clear designation of emergency exits is the most commonly used OHS practice and it is implemented by 75.80% of organizations surveyed. In regard of organization type, this OHS practice is applied by 89.20% of manufacturing organizations and by 66.70% of trading ones.

Periodically conducting safety briefings is implemented in total by 74.70% of organizations surveyed. This practice to ensure the health and safety of warehouse workers is used by 83.80% of manufacturing and 68.50% of trading organizations.

Provision of appropriate work clothing and PPE is implemented by 68.10% of the organizations surveyed. The importance of this OHS practice is greater in manufacturing warehouses than in trading ones. It is used by 86.50% of manufacturing and 55.60% of trading organizations.

Placement of signs/work instructions for safe work at the workplace is implemented by 75.70% of manufacturing organizations and 53.70% of trading ones or in total by 62.60 % of the surveyed organizations.

About half of surveyed organizations are adapting warehouse infrastructure as a measure to improve the

health and safety of warehouse workers. This OHS practice is applied by 62.20% of manufacturing and 38.90% of trading organizations.

The most underestimated OHS practice seems to be the joint firefighting drills with fire and emergency safety authorities, which is applied in total by 30.80% of organizations surveyed. It is applied by 43.20% of manufacturing and 22.20% of trading organizations.

Individual differences in terms of OHS practices applied and organization size are presented in Figure 2.

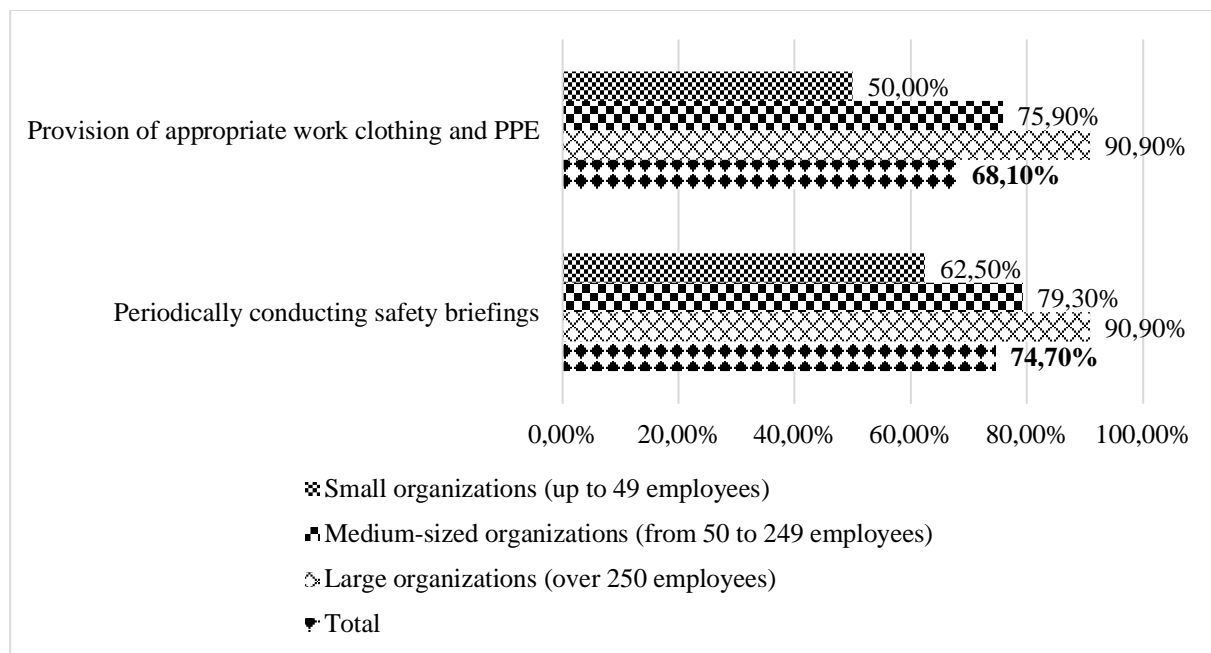


Figure 2 OHS practices applied in Bulgarian manufacturing and trading organizations - overall and by organization size
Source: author's calculation

Data analysis shows that the practices of providing appropriate work clothing and PPE, as well as periodically conducting safety briefings are used by 68.10%, and 74.70% of organizations surveyed, respectively. These measures to ensure OHS are mainly used in large and medium-sized organizations, and small ones lag behind them. Small organizations often cannot afford to hire an OHS specialist and have more limited financial resources to provide OHS measures at work.

Appropriate work clothing and PPE, as well as periodical safety briefings are implemented by 90.90% of large organizations and by 75.90%, and 79.30% of medium-sized organizations, respectively. Small organizations are generally in a catch-up position, and a smaller proportion of them apply these practices, compared to the share of medium and large ones. Providing work clothing and PPE is implemented by 50.00% of small organizations, and conducting periodic safety briefings by 62.50% of them.

5 Discussion

Contemporary trends in trading warehouses that build up better opportunities for faster order fulfillment in e-commerce involve both an increase in stock density and higher degree of automation [23]. They lead to high intensity of material flow. As a result, health and safety risks of warehouse workers are increased, while OHS practices in the warehouses of the Bulgarian trading organizations are noticeably weaker than in manufacturing ones. Therefore, it is imperative that trading warehouse managers expand protection measures of warehouse workers.

The finding that the surveyed organizations downplay the importance of joint firefighting drills with fire and emergency safety authorities for OHS ensuring in the warehouses is also a source of concern. This comes against the backdrop of worrying data from the US National Fire Protection Association. They show that for the period 2016-2020 in the US only, an average of 1,450 warehouse fires occur annually, killing an average of 2 civilians and

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injuring 16 others [24]. This indicates that a wider application of joint firefighting drills is necessary in the studied organizations. In particular, this need is even more pressing for trading organizations, which apply this OHS practice noticeably less compared to manufacturing ones. Some of the most significant fires in recent years claimed a number of victims among both workers and firefighters in warehouse incidents in Tianjin, 2015 [25], Changchun, 2021 [26], Moscow 2016 [27,28], 2022 [29], Orlando, 2022 [30], and hundreds of thousands square-foot property in fire incidents in Indiana 2022, Illinois 2022, and North Carolina 2021 [23].

The warehouse work environment is highly hazardous. In manufacturing and trading warehouses, high intensity movement of lifting transport equipment and pedestrians as well as intense pressure to reduce customer service times are observed. Hence, the higher risk to health and safety of warehouse workers. Available data shows that forklift accidents account for around 10% of workplace injuries [31] and they are often caused by a collision between a forklift and a warehouse worker [32]. Therefore, the need to adapt the warehouse infrastructure arises. Various measures such as improving the lighting, installing guardrails, delineating separate areas for the movement of forklifts and pedestrians, as well as installation of signal warehouse traffic warning light system contribute to reduction of warehouse occupational injuries.

The decrease of occupational injuries for warehouse workers is a key prerequisite for reducing work injury costs, workers' compensation costs, absenteeism and improvement of the employer brand trust. Although the employment injury insurance scheme options are constantly expanding, they are still overwhelming for many employers. As a result, ensuring health and safety at work continues to be one of the most significant challenges for business managers, and warehouse managers in particular. According to a study conducted by The International Labor Organization and The United Nations Global Compact, around 60% of the global workforce lacks protection against work-related injury and illness [15]. In addition, data from the National Safety Council show that in the US private sector, employers lost the opportunity to use significant number of workers of all ages due to injury or illness in 2020 – 22.1; 27.3 and 28 workers per 10,000 employed, respectively for a period from 6 to 10; 11 to 20 and 31 + working days [33]. This gives rise to the need for constant prevention of occupational accidents in the risky warehouse environment and the wider application of practices for warehouse workers' protection. In Bulgarian trading organizations warehouses this necessity is clearly expressed. The study results show that warehouse workers in these storehouses receive less protection in terms of some OHS practices such as clear designation of emergency exits, placement of signs/work instructions for safe work at workplaces, provision of appropriate work clothing and PPE, and periodically conducting safety briefings, in comparison

with surveyed manufacturing organizations. A need to expand protection practices in small-sized organizations that lag behind medium and large ones in implementation of mandatory OHS measures such as provision of appropriate work clothing and PPE, as well as periodically conducting safety briefings is also observed.

Based on the results of the analysis, several recommendations to warehouse managers and policy makers can be drawn up.

First, better warehouse workers protection can be achieved through a wider implementation of OHS practices by a greater number of trading organizations. Moreover, hiring a part-time OHS specialist or training such an expert at the organization's expense would also contribute to OHS improvements in trading warehouses.

Second, reducing the health and safety risks for workers as a result of fires requires warehouse managers in Bulgarian manufacturing and trading organizations to conduct joint firefighting drills with fire and emergency safety authorities at least once a year.

Third, advancement of investments to ensure a safer working environment can be accomplished with legislative initiatives by policy makers. Measures such as tax reductions on the amount of investments to adapt the warehouse infrastructure and/or provision of low-interest investment loans by the Bulgarian Development Bank would contribute to better protection of warehouse workers in Bulgarian manufacturing and trading organizations.

Fourth, establishing an association that promotes OHS of warehouse workers would contribute to increasing the expertise and synergy in the field of safety in a warehouse environment of member organizations. It would facilitate the interaction between warehouse managers and policy makers by formulating common positions to support regulatory framework updating and changing. In addition, the association expert committees could support warehouse managers by drawing up recommendations, instructions and guides for conducting periodic safety briefings, tailored to the peculiarities in a warehouse environment.

Fifth, policy makers could create conditions for acquisition of suitable work clothing, PPE and protection signs to expand OHS practices applied in the warehouses of small, medium and large-sized manufacturing and trading organizations in Bulgaria by including an appropriate application mechanism in the operational programs financed by the European Structural Funds for Bulgaria.

Sixth, ISO 45000 management system certification can also help to build a culture of prevention and better control of health and safety issues in warehouses. It can be done with the support of policy makers and the provision of an appropriate application mechanism under the operational programs of the European Structural Funds for Bulgaria.

6 Conclusion

The results of this research provided some valuable initial scientific inferences and practical recommendations regarding the OHS practices of warehouse workers in Bulgarian manufacturing and trading organizations. The study outcomes laid out an answer to the research questions posed. They can be summarized as follows:

First, some fundamental and frequently used OHS practices of warehouse workers are identified. These are: general training on health and safety at work; first aid training; demonstrations of available equipment safety use; joint firefighting drills with fire and emergency safety authorities; periodically conducting evacuations of warehouse workers and visitors; adaptation of warehouse infrastructure; use of equipment for protective signals; clear designation of emergency exits; designation of places with first aid kits; placement of signs/work instructions for safe work at workplaces; provision of appropriate work clothing and PPE, as well as conducting periodic safety briefings.

Second, existence of statistically significant relationships between some of OHS practices applied and research variables are established. Such relationships between six of OHS practices and organization type are observed. These practices are clear designation of emergency exits; periodically conducting safety briefings; provision of appropriate work clothing and PPE; placement of signs/work instructions for safe work at the workplace; adaptation of warehouse infrastructure, as well as joint firefighting drills with fire and emergency safety authorities. Statistically significant relationships regarding OHS practices related to provision of appropriate work clothing and PPE, periodically conducting safety briefings and organization size are also established.

Third, the provision of appropriate work clothing and PPE is a practice that is characterized by a medium relationship strength, both in terms of organization type and organization size. All other statistically significant relationships between OHS practices applied and research variables are weak.

Fourth, the individual differences in the statistically significant relationships show that OHS studied practices are applied more frequently in the warehouses of manufacturing organizations than in those of trading organizations. Moreover, fundamental practices of high importance for OHS ensuring of warehouse workers, such as joint firefighting drills with fire and emergency safety authorities, and adaptation of warehouse infrastructure are used more limitedly - totally by 30.80 % and 48.80 % of organizations surveyed, respectively. In addition, small organizations lag behind medium- and large-sized organizations in terms of implementing practices for providing appropriate work clothing and PPE, and periodically conducting safety briefings.

Fifth, some recommendations to improve the OHS practices of warehouse workers aimed at stakeholders are inferred. The main guidelines to warehouse managers are

related to hiring a part-time OHS specialist or training such an expert at the organization's expense, conducting joint firefighting drills with fire and emergency safety authorities at least once a year, as well as participation in establishing an association that promotes OHS of warehouse workers. The recommendations to policy makers are related to building an appropriate regulatory environment and creating conditions for wider application of OHS practices. Appropriate measures in this field involve tax reductions on the amount of investments to adapt the warehouse infrastructure, provision of low-interest investment loans by the Bulgarian Development Bank and provision of an appropriate application mechanism under the operational programs of the European Structural Funds for Bulgaria with the purpose of acquisition of suitable work clothing, PPE, protection signs, as well as ISO 45000 management systems certification.

The present research also has some limitations. They stem from the relatively small sample size, the engagement of a limited number of fundamental OHS practices, the use of only qualitative variables, as well as the narrow focus solely on manufacturing and trading organizations in supply chains. Overcoming these limitations in future research will require expanding the sample scope, investigating a more comprehensive set of OHS practices applied, selecting quantitative variables in order to create conditions for the application of more advanced statistical tools and inclusion of additional supply chain participants - suppliers of raw materials or/and logistics service providers.

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Predicting crash injury severity in road freight flows with association rules algorithms

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Keywords: Association rule mining, Apriori algorithm, crash risk prediction, road freight transport.

Abstract: The purpose of this study is to evaluate the use of the Apriori association rule mining algorithm to classify and predict the severity of the 718,565 accidents involving freight transport vehicles in Mexico, which occurred between 2009 and 2018. The accidents were classified into those in which there was only material damage or injured people {Severity=0} and in those in which people died {Severity=1}. 115 association rules were obtained, 79 corresponding to non-fatal accidents, and 36 to fatal ones. The main factors associated with the severity of the accident belong to male subjects, involved in accidents that occur on weekends and in suburban areas, and where the probability of the accident being fatal is 1.69 times greater. Thus, the results of using the association rules to relate demographic and circumstantial characteristics of the accident with the severity of the injuries show an accuracy of just over 65%. Therefore, despite the limitations that may occur due to the omission of relevant variables, and the fact that the results show little precision, the feasibility of using machine learning techniques and, specifically, the association rules as promising tools to help analyze accidents and help launch road safety interventions more effectively is manifested.

1 Introduction

In Mexico, each year over sixteen thousand people die as a consequence of a road accident [1], this is equal to 132 deaths per million inhabitants, which is why this cause represents a severe problem of public healthcare. Regarding, this country, diverse studies have been realized in order to analyse the trend of deaths and injuries of motorbikes, bicycles, drivers and pedestrians, as well as the prevalence in the use of helmet, safety belt or alcohol consumption, among other subjects about risk factors [2-4]. As far as accidents in road freight transport, in logistics activities, over 2500 deaths per year are acknowledged, and the accidents are recorded by the National Institute of Statistics and Geography [5] and the Mexican Institute of Transportation [6].

The records include general characteristics of the accidents, in which the types of vehicles are included, as well as the behavioral and socioeconomic data from the injured people. However, despite the great deal of information, the data analysis reduces to the descriptive statistics, and only in some case of correlational manner [7]. Likewise, though in international literature the risk factors of road accidents have been widely [8], the research about road accidents of road freight transportation in

Mexico are very limited and it hasn't been deeply investigated about the groups and characteristics of drivers in road freight flows which have particularly high risks of accident [9]. In this sense, the data have been wasted and, as a result, their potential has been limited in the elaboration of public policies or in business programs for accident prevention.

The great amount of available information requires applying interdisciplinary methods of data analysis and realizing studies of an explanatory-casual kind, generalizing behaviors or making inferences in such way that the patterns of relationships between the variables could be acknowledged and extract a better understanding of the high volume of data. Under this context, this research started with the purpose of identifying explanatory or predictive variables of the fatalities of the road freight transport, in which the flow of goods takes place, and as a case study of the statistics of Land Traffic Accidents in Urban and Suburban Zones (ATUS) of the INEGI. Multivariate analysis techniques were attempted; however, the assumptions were not met, or the data did not fit the models. It is how it was thought to use machine learning techniques and, in order to predict the severity of traffic accidents in freight transport in Mexico, the supervised technique of association rules with discrete labels was used

to relate the variables of accidents with the severity of the injuries, that is to say, whether or not it was fatal.

2 Literature review

Technological advances in sensors, positioning systems, information collection devices and, in general, smart devices connected to communication networks provide a large amount of data in all areas and activities on the planet. In this sense, transport is one of the activities with the greatest number of applications; this is demonstrated by Tang et al. [10] who conducted a review of the Big Data literature in forecast research and found that, in addition to a rapid growth in the number of investigations, about 16.55% of the so-called hotspots correspond to transportation issues, and 11.38 % to traffic forecast models.

Therefore, it is not surprising that there are more and more records and information on traffic accidents, transport systems and logistics activities, which generate more research on the application of Data Science to predict, classify and identify the causes of incidents with new models and techniques that improve prediction and information on future prospects in complex situations, without linearity or seasonality.

In this sense, to try to explain the behavior of accidents, all kinds of machine learning techniques have been used. For example, Iranitalab and Khattak [11] used Multinomial Logit (MNL), Nearest Neighbor Classification (NNC), Support Vector Machines (SVMs) and Random Forests (RF) to predict the severity of traffic accidents; and they conclude that NNC had higher prediction accuracy in general and in the most severe crashes, the RF and SVMs methods followed with sufficient performance, while the MNL method was the weakest.

On their behalf, Arhin and Gatiba [12] used Gaussian naïve Bayes classifiers and support vector machines (SVMs) algorithms to predict the severity of injuries caused by accidents at intersections without traffic lights. Although the first technique had very low performance with an accuracy of 48.5%; with the second, SVMs, they achieved an accuracy of 83.2%, so they conclude that these models can be applied by transportation officials to recognize and perform necessary mitigation actions at collision-prone intersections.

Das et al. [13] also made predictions for injury severity in pedestrian-involved crashes in two cities in the United States and evaluated three algorithms: support vector machines (SVMs), random forests (RFs) and Extreme Gradient Boosting (XGBoost). In this study, different levels of precision were found for each of the evaluated cities and the different algorithms; for SVMs 0.6250 and 0.5849, for RF 0.6250 and 0.5769, and for XGBoost 0.7059 and 0.66. Thus, the best performance was for the XGBoost algorithm.

These studies show that there is no clear hierarchy of methods in terms of their performance in predicting the severity of injuries in traffic accidents. In addition, there

are several studies that use techniques such as association rule mining (ARM) to identify sets of attributes and subgroups with a higher probability of severity in traffic accidents [14-16]. Yao et al. [17] found with ARM that the behavior of road users, vehicle factors, geometric characteristics of the road and environmental conditions are among the factors associated with severe traffic accidents. Likewise, Feng et al. [18] found a strong correlation between accidents and environmental factors, speed, and location.

Nonetheless, the studies that use association rules to identify sets of factors that determine the severity of accidents show the importance of carrying out analyzes in geographical locations, with different cultural factors, and for each of the types of transport. Thus, for example, another study analyzing motorcycle accidents with ARM in Australia [19] shows that among the factors with a higher probability of severe injuries are the collision with a truck or a static object, the accident while trying to pass a car or with a vehicle from the opposite direction, and during certain periods of the day, either during early morning or late at night. While Das et al. [20] found that lighting conditions, vehicle turns, and the age range of pedestrians 45 years and older, are frequently present in the factors determined by the association rules.

However, even though these methods have been in use for several decades, there are still relatively few studies on the severity of road accidents. In this way, the diversity of factors determined by the region and culture make it significant to investigate the elements that influence the severity of traffic accidents, the different road users, and the various types of transport; in order to provide perspectives that help understand the causes of the severity of injuries, and develop initiatives and effective public policies that help reduce the severity and deaths caused by traffic accidents.

3 Method

Open data corresponding to the period between 2009 and 2018 of the statistics of Land Traffic Accidents in Urban and Suburban Zones (ATUS) of the National Institute of Statistics and Geography [5] were used. Ten annual files were collected, for which a total of 3,889,989 records of traffic accidents were accumulated. All claims involving a cargo transport vehicle were selected, and participate in the flow of goods, giving a total of 891,172 records corresponding to 22.9% of the total.

Specifically, for the selection of these records, the variable type of vehicle was used, which INEGI [21] classifies into thirteen categories, and among which there are three types of vehicles dedicated to the goods flow; cargo vans, with a capacity of up to one ton; cargo trucks, which carry between one and five tons; and tractors with or without a trailer, which transport more than five tons of goods. After discarding the null records, the database on cargo accidents for the study decade consisted of 718,565

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records, 7,464 classified as fatal accidents {Severity=1} and 711,101 as non-fatal {Severity=0}.

Subsequently, with multivariate analysis techniques, an attempt was made to identify explanatory or predictive variables of fatalities in freight transport; however, the assumptions of normality, homoscedasticity, multicollinearity, or the nature of the variables were not met; even some methods of interdependence froze the computer. Given the binary nature of the main variable, which refers to whether there were fatalities in the freight transport accident, it was considered to use binary logistic regression. However, even though the global precision was 76.5%, the sensitivity had a very low value (1.8%), and the total goodness of fit ($P < 0.001$) showed that the data do not fit the model.

This is how it was thought to use machine learning techniques and, with the objective to predict the severity of traffic accidents in freight transportation in Mexico, the supervised technique of association rules was used to investigate among the variables related to the fatalities in traffic accidents of vehicles that execute the flows of goods by road.

4 Association rule mining

The Arules package, created by Hahsler et al. [22] was used for the programming environment, R. Arules provides a basic data analysis infrastructure that results in a set of elements and association rules [23] with a interface capable of processing the Apriori algorithm proposed by [24].

Essentially, the algorithm consists of analyzing a subset of elements contained in the attributes, which give rise to a rule defined as an implication of the form if $X \Rightarrow Y$; where

the patterns obtained in the sets of elements X, which are called antecedents or Left-Hand-Side (LHS), can be used to predict the class of unclassified records Y, called consequential or Right-Hand-Side (RHS). In addition, the Arules package outputs a diversity of rules, with their respective confidence (1), support (2) and lift (3) values, to quantify the statistical strength of the different patterns. The software internally calculates the parameters with formulas such as the following:

$$Confidence(\{X\} \rightarrow \{Y\}) = \frac{Transactions\ containing\ both\ X\ and\ Y}{Transactions\ containing\ X} \tag{1}$$

$$Support(\{X\} \rightarrow \{Y\}) = \frac{Transactions\ containing\ both\ X\ and\ Y}{Total\ number\ of\ transactions} \tag{2}$$

$$Lift(\{X\} \rightarrow \{Y\}) = \frac{(Transactions\ containing\ both\ X\ and\ Y)}{(Fraction\ of\ transactions\ containing\ X)} \tag{3}$$

For the case study of this research, the Apriori algorithm was executed with variables from the statistics of Land Traffic Accidents in Urban and Suburban Zones (ATUS), which includes aspects related to people: sex and age; behavioral variables: alcoholic breath and use of seat belt; temporality variables: related to the month of the year, the day of the week, and the time of day; and the variables related to the road, which include the region of the country, and whether or not it is an urban area. The variables that were used, and their discretized values are shown in the following (Table 1).

Table 1 Definition and categorization of variables

Variable	Description	Values
Sex	Sex of the driver	1 Male 2 Woman
Alcoholic	Evidence of alcoholic breath	1 Yes 2 No 3 It is ignored
Belt	Usage of safety belt	0 No 1 Yes 3 It is ignored
Region	Region of the country where the accident happened	1 Northwest Zone 2 Northeast Zone 3 Occident Zone 4 Center Zone 5 Southeast Zone
Season	Season of the year in which the accident happened	1 Spring 2 Summer 3 Fall 4 Winter
Time	Time of day when the accident happened	1 From 00:01 to 05:59 2 From 06:00 to 11:59 3 From 12:00 to 17:59 4 From 18:00 to 23:59

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Weekend	Day of the week in which the accident happened	1 From Monday to Friday 2 Saturday and Sunday
Urban	If the accident happened in Urban Zone	0 Suburban Zone 1 Urban Zone
Age	Age Group	1 From 1 to 20 years old 2 From 20 to 30 years old 3 From 31 to 40 years old 4 From 41 to 50 years old 5 51 or older
Severity	Severity of the accident	0 Non-fatal 1 Fatal

Thus, considering these variables, it is sought to explain the severity of the accidents. For this, the records were classified in which there were only material damages or injured persons {Severity=0} and in which there were deceased persons {Severity=1}. In this sense, for the prediction of fatalities in traffic accidents in freight transport in Mexico, the consequences that refer to accidents in which there were deceased persons were filtered {Severity=1} and their statistical factors were analyzed, to determine the antecedents with the patterns with the most significant associations.

Previously, the variables were decodified and established discretely and encode as a factor. To avoid overfitting and rebalancing the classes between fatal {Severity=1} and non-fatal {Severity=0} accidents, just over one hundredth of the non-fatal records (n=7,463) was randomly selected. These were combined with fatal accidents (FatalAcc; n=7,464) to form a database on rebalanced load accidents (Accdf_Rebalanced).

To monitor the algorithm, the rebalanced data set (n=14,927) was separated into two groups: the first (Accdf_train), denominated as the training set and made up of 70% of the records, and; the second (Accdf_test) that contains the rest of the data (30%) and, was named the test set. Therefore, using the training data, the Apriori algorithm was executed and the rules and associated parameters were obtained. However, given that what was sought was to identify regularities between the different variables and the accidents where there were deceased persons {Severity=1} or not {Severity=0}, a filter was applied on the consequent, to only consider those related to the accident fatality variable (Severity).

Subsequently, using the test data and, to determine the number of rules that each of the records meet, two functions were used: one that fragments the rules and serves to identify the values of the different attributes that integrate each of the rules (function ruleSeparation from

the code in the supplemental material); and another that compares and quantifies the rules with the values of the cases, in such a way that it is possible to know which cases meet one or more of the rules (function RuleVsCases).

The number of rules per case was considered as the classification threshold, which is why the sensitivity, specificity and precision of the model were calculated considering from the fulfillment of one and up to ten of the rules in each record. Once the number of rules that presented the best indicators for classification had been established, the prediction of the group belonging to the initial set that contains all the records in which a cargo vehicle was involved was made and; based on this set of rules, the variables related to the level of severity of the accident were established. The R code and data used, including all commands and functions to generate all results, graphs and figures shown in this document, are included in the supplementary material.

5 Results

By applying the Apriori algorithm on the training data (with parameters support = .1, confidence = .5), 785 association rules were obtained. After applying the filter on the RHS to consider only accidents according to the category of whether there were {Severity=1} or not {Severity=0} deceased persons, a total of 115 rules were obtained, 79 associated with accidents where there were not deceased persons, and 36 where there were. Figure 1 shows a graph that considers the support (in the size of the spheres) and the lift (according to the intensity of the color) and it can be seen that, despite not having cases where both values are high, there are combinations where fatalities in cargo transport {Severity=1} show high lift or high support, so it can be inferred that there is a set of rules where fatalities are an important consequent.

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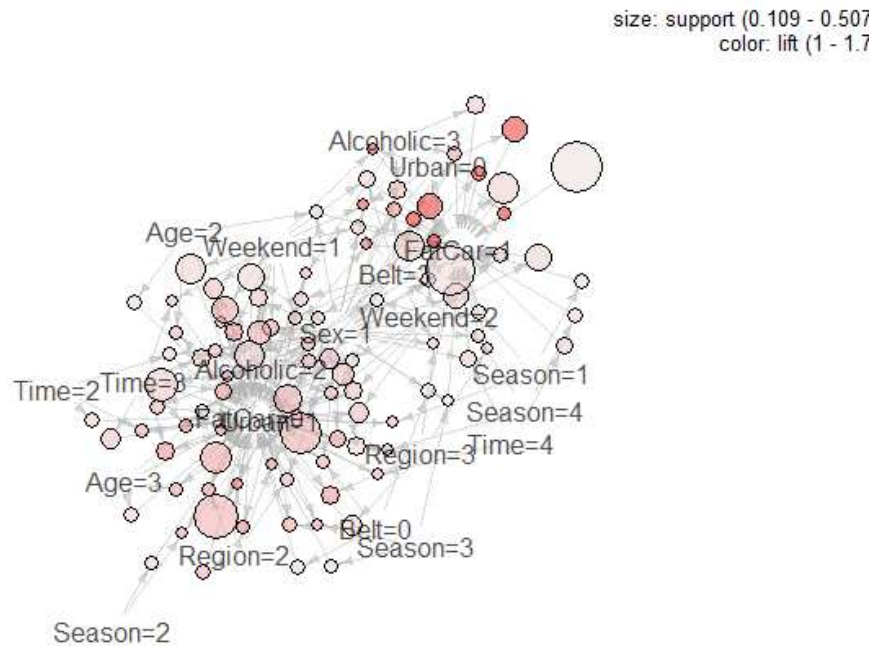


Figure 1 Association rules graphic

Likewise, while inspecting the rules it was found that, for example, when the driver is male, the accident occurs on the weekend and in a suburban area, {Sex = 1, Weekend = 2, Urban = 0} the probability that the accident is fatal is

1.69 times greater. The antecedents and consequences of other rules, as well as their associated parameters can be seen in (Table 2).

Table 2 Some association rules and their associated parameters

LHS	RHS	Support	Confidence	Coverage	Lift	Count
{Weekend=2,Urban=0}	=> {FatCar=1}	0.127459	0.862887	0.147712	1.700279	1309
{Sex=1,Weekend=2,Urban=0}	=> {FatCar=1}	0.123661	0.862186	0.143427	1.698897	1270
{Sex=1,Urban=0}	=> {FatCar=1}	0.234177	0.847129	0.276436	1.669228	2405
{Sex=1,Weekend=1,Urban=0}	=> {FatCar=1}	0.110516	0.830893	0.133009	1.637236	1135
{Weekend=1,Urban=0}	=> {FatCar=1}	0.114703	0.825508	0.138948	1.626625	1178
{Sex=1,Alcoholic=2,Urban=0}	=> {FatCar=1}	0.106134	0.794461	0.133593	1.565447	1090
{Alcoholic=2,Urban=0}	=> {FatCar=1}	0.109542	0.791696	0.138364	1.560000	1125

The occurrence in suburban areas, gender, the use of the seat belt and the season of the year in which the accident occurs are attributes that are repeated several

times in the different rules; This can also be seen in Figure 2, where a graph of support bars by frequencies is shown with the ten elements that are repeated the most.

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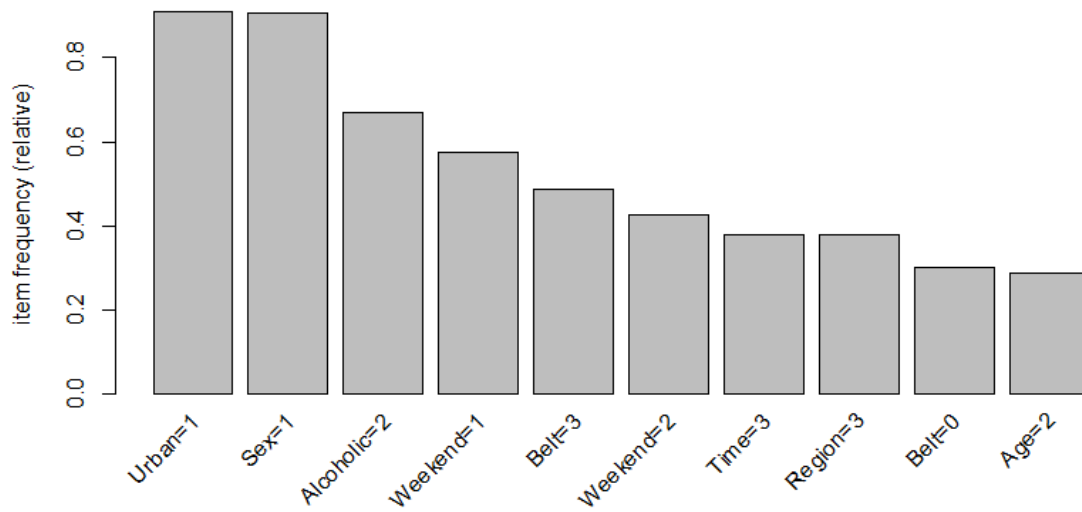


Figure 2 Frequency bar plot

Nonetheless, it is known beforehand that these variables represent risk factors and that, therefore, they increase the probability that the accident is [8]. Given it is sought to identify the elements that are related to fatalities in freight transport accidents, the function to separate rules (ruleSeparation) and another to compare with the cases (RuleVsCases) was used. With these functions, it was possible to identify whether the variables, for each of the

cases, obtained the values indicated by the association rules, in addition to quantifying the number of rules that are fulfilled per case. The histogram of Figure 3 shows the frequency of the rules associated with accidents with fatalities and the frequency presented in the test data, it can be seen that, for eight rules per case, the highest frequency of fatalities in vehicle accidents is presented freight involved.

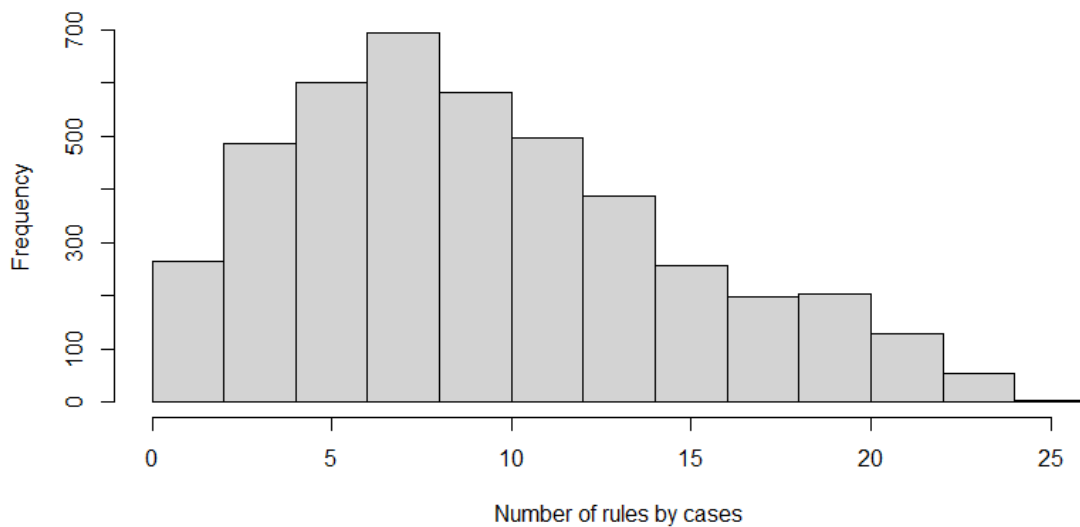


Figure 3 Histogram of the number of rules per case

In this way, eight or more rules are proposed per case to determine the discrimination threshold and, therefore, if the forecast of the cases will be established as a fatal load accident {Severity=1} or as an accident without fatalities

{Severity=0}. Thus, by applying the rules to the test data and classifying the cases that are within the threshold, the confusion matrix can be established (Figure 4).

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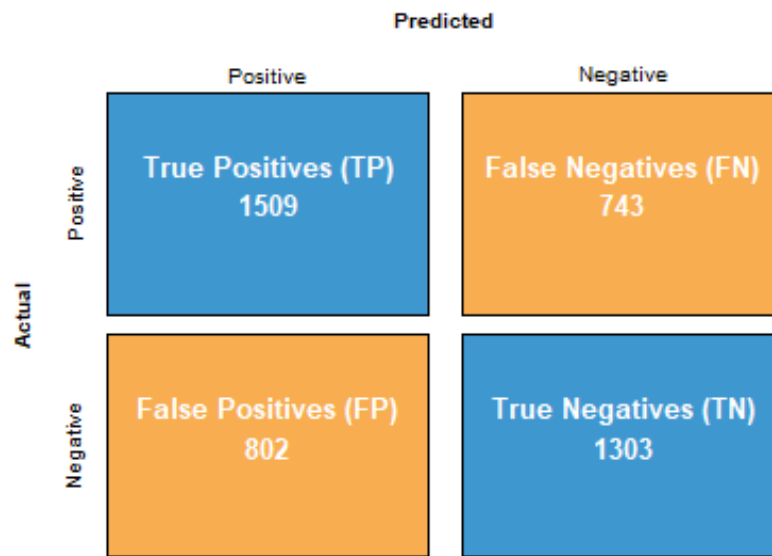


Figure 4 Confusion Matrix for the threshold of 8 or more rules

In addition, if the sensitivity, specificity and precision of the predictions are graphed with different thresholds according to the number of rules, Figure 5 is obtained. In this, it can be seen that near the eight rules per case is where

the balance between the value of the sensitivity and that of the specificity is obtained; and values of 0.67 are obtained for the sensitivity, 0.62 for the specificity, and 0.65 for the precision.

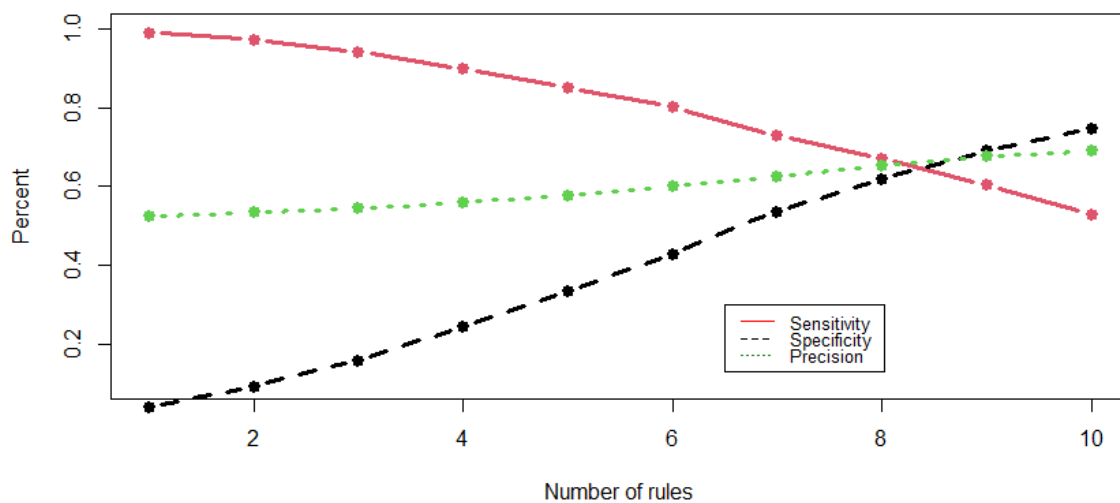


Figure 5 Sensitivity, specificity and precision of the model by number of rules per case

6 Discussion and conclusions

Every day the use of technologies that record information is being integrated and, therefore, a large amount of data on transport and the supply chain activities is being accumulated. Most of the databases are not analyzed in their entirety, they have non-linear relationships, the models are of the non-deterministic polynomial-time hardness (NP-hardness) class or the meta-analyzes are short-range.

The analysis of traffic accidents is an essential task for freight transport companies, and avoid breaks in the flow

of goods. However, in Mexico, there is a gap in accident investigation methodology, as most investigations are based on traditional statistical methods.

Thus, it is highlighted the importance and growth that data mining and different machine learning techniques have had to discover patterns, generalize behaviors and make inferences that help to understand traffic accidents better; among which there are, for example, neural networks [25], regression trees [26] or text mining Techniques [27].

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In addition, the use of machine learning techniques has become cheap and easy to apply due to free software, such as R or Python, which include libraries and functions that form a very flexible and extensible work environment, and that make it possible to systematize in a constant basis the analysis of information.

In this study, an extensive set of data on traffic accidents in Mexico is used and the Apriori algorithm of association rules is applied to predict the severity of accidents in freight transport. The results of using the association rules to relate the demographic and circumstantial characteristics of the accident with the severity of the injuries show a precision of just over 65%.

It can be inferred that the level of imprecision may be due to the nature of the variables; given that the records are retrospective and were not specifically designed to classify their severity. For example, in the international literature there are well-known risk factors regarding the increase in the severity of the accidents; These include the speed at which the vehicles circulate, weather conditions such as rain, snow or fog, ergonomic conditions of the vehicle, psychosocial factors and the drivers' days, among other working conditions that are not included in the database and which may be omissions of relevant [8,9].

The use of association rules is an alternative that, in addition to indicating the possibility of an accident due to the exposure to some risk such as the odds ratios of traditional epidemiological methods, can be used to classify individuals with a set of characteristics or who are found under specific circumstances or patterns. Therefore, despite the limitations and the fact that the results show insufficient precision, the association rules are a promising tool in the analysis of traffic accidents and, therefore, to provide elements that contribute to launching interventions of road safety more effectively, and that at the same time allows the correct flow of merchandise in logistics activities.

It is proposed to use machine learning algorithms in companies dedicated to the transport of goods with data collected according to a theoretical framework on risk factors in freight transport. In addition, the group of drivers who carry out their journeys without mishaps must be included to establish the variables and characteristics of the protective factors. In this way, characteristics of the drivers, shipments and vehicles of each of the trips that the company makes will be obtained, under the premise that better performance will be obtained, and a more practical application, when applying the algorithms to identify the variables related to accidents and, therefore, in the prediction of the conditions and the drivers that represent less risk.

In conclusion, these types of prediction models help to identify the particularities of those injured and killed by traffic accidents. The determination is relevant in the sense that the characteristics must be used for the elaboration of government actions that promote protective factors and, therefore, reduce the number of accidents and ruptures in

the flow of goods that are transported by road. One strategy could be the development of road safety campaigns in which the factors and attitudes that drivers carry out and that lead to accidents are disclosed. Kolter [28] indicates that a campaign to change social behavior must contain some guidelines such as identifying the objective, the factors that prevent the negative attitude of the people to whom the campaign is directed, validation and feedback, execution, monitoring, and campaign evaluation. In general, in Mexico, there are very few efforts and there are very few campaigns dedicated to the self-transportation of cargo, rather they are dedicated to cars to avoid driving under the influence of alcohol, fatigue, or for the use of seat belts.

Thus, with the information resulting from these analyses, and if this type of model is used, it will be possible to establish categories that integrate common arguments and that contemplate both physical, chemical, biological, and mechanical risks; demands derived from the organization and technical division of labor; and elements related to psychosocial and behavioral factors. With this information, alternatives should be sought in the media that are accessible to professional drivers, among these could be social networks, the radio, training courses, the facilities where they load and unload, or where they process their driver's licenses. It is also important to use the mass media and place billboards on-road sections as a graphic means of advertising information.

Acknowledgement

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Telework and the limited impact on traffic reduction – Case study Madrid (Spain)

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Keywords: telework, telecommute, traffic impact, traffic occupancy.

Abstract: Teleworking has been proposed by organizations and policymakers as a key strategy to help reduce the number of commutes and boost employee satisfaction. Since telework may be linked to a tool to reduce traffic in urban areas, this research aims to determine the impact that telework has on traffic congestion in Madrid (Spain), given a post-Covid19 context in which many organizations have implemented teleworking in the long term. This study provides evidence that teleworking has had a limited favourable impact on traffic in the city of Madrid based on the correlation between telework implementation and the traffic data collected from 7.365 traffic sensors located in Madrid that are distributed and managed by the Madrid City Council. Covid19 represents an influx point with regard to telework implementation, allowing this kind of research to interpret the answer to the question. The results of our research, through regression calculations and Pearson's correlation coefficient, show that telework in the city of Madrid does not generate a positive impact on traffic during peak times proportional to the increase of telework, as expected based on the existing literature. However, there are other elements that influence the modal choice that may affect this correlation, considering that teleworking allows people greater residence flexibility and that residence location and distance to the workplace are factors that significantly influence the modal choice of transport.

1 Introduction

Home-based telework, also known as teleworking, a labour methodology that allows employees to work from home to the extent the job allows, emerged two decades ago from developments in information and communication technologies (ICT). The number of workers who could potentially work from home has grown over the years and due to the Covid19, this labour methodology has become firmly established [1,2].

Telework has led to a paradigm shift in urban mobility, given that the main purpose of transit in urban environments is commuting [3-5]. The fact that residents can work from home contributes to a reduction in the number of commuters in absolute terms [6,7] and can prompt a significant change in urban mobility. Telework represents an opportunity to improve environmental sustainability [8], as it is an efficient and sustainable measure that is viewed favourably by consumers since it does not imply a significant cost and provides indirect benefits in terms of economic savings and work/life balance [9].

Thus, this phenomenon has prompted an increase in the number of studies and research evaluating the effect that the telework has on urban traffic since it may help reduce commuters. Some studies suggest there is a positive impact [10-12], while others conclude differently

suggesting telework has no clear impact on traffic improvement [13]. The different research methodologies and various geographies studied may explain the varying points of view. Also, several studies point out the impact that telework may have on home location [14] and the resulting effect on the mobility patterns and transport behaviour for the employees who work from home. Teleworkers tend to have longer commute distances than others [15-17] which impacts travel patterns with regards to means of transport and vehicle use. The impact that telework may have on travel patterns is influenced by other factors such as frequency of days working from home [7], commute distance [12,18,19] and commute travel time [20,21].

This research aims to provide an exhaustive literature review and a make new contribution to the impact of telework on traffic by analyzing the evolution of congestion in the city of Madrid during peak times in correlation with the establishment of telework to determine the relationship in between both variables, based on information provided by the Madrid Council and gathered from 7.360 traffic sensors throughout the city.

The analysis is carried out specifically in the city of Madrid (Spain). As the sixth most populace region in Europe [22] and the third most populace metropolitan area in Europe [23], there is a high percentage of organizations

that have implemented telework [5,24] and an equally high percentage of white-collar workers. In addition, Madrid has a series of environmental characteristics—cultural, labour-related, economic, climatological, educational, etc.—that influence the choice of means of transport [25].

Since Covid19 helped telework globally, this research aims to offer new evidence from Madrid after pandemic disruption compared to the literature published prior to Covid19 when the teleworking situation was significantly different. The justification for the study lies in the fact that telework represents a paradigm shift within organizations and for urban mobility given that this type of work-related travel accounts for a high proportion of aggregate travel and, above all, the change that telework exerts on the lifestyle of residents, significantly influencing means of transport choice for commutes.

2 Literature review: impact of telework on urban mobility and traffic

2.1 Mobility and teleworking patterns of Madrid city

The city of Madrid is the sixth most populace region in Europe with 6.62 million inhabitants[22]. According to the most recent survey on Madrid's population mobility [26], there are roughly 15,847,266 daily commutes within the region, while in the city's local area, the number of trips amounts to 7,728,000. Taking into account suburban Madrid, given its proximity, the number of daily trips totals 14,680,000. Twenty-seven percent of daily trips are work-related. Excluding walking trips, the percentage of daily work-related commutes rises to 36.7%. Likewise, of these total commutes, 58.9% are made using private vehicles, while the remaining 41.1% use public transport. These figures show a high percentage of private vehicle usage for work-related trips among Madrid residents, which poses a challenge for transportation authorities to plan and scale the urban infrastructure, while at the same time encouraging the use of public transport. Madrid has an extensive public transport system, with the second most extensive metro in Europe (after London [27]). Therefore, public transport providers must keep working to increase public transport usage rates.

Due to the Covid pandemic and the corresponding healthcare measures implemented, companies were forced to adopt teleworking systems in light of the restrictions imposed by public administrations, which led to an increase in the percentage of teleworkers in the European Union, from 15% in 2018 to 25% in 2020 [28]. In 2019, only 8% of employed residents in Madrid were teleworking [5], while as of September 2022, this figure rose to 23% [5, 24, 29]. It is important to note that the type of telework offered differs from one company to another, according to logistics, and organizational and operational needs; for example, remote work can be carried out full-time or part-time on weekly basis. In 2021, Madrid's 3.2 million

telecommuters averaged 3.5 remote working days per week [30].

2.2 Impact of telework on urban mobility and traffic

Mobility in urban environments depends on the means of transport chosen for the journey. The choice of means of transport depends on various cultural [31] and environmental factors [32], but especially on the motivation for the trip [33]. In Europe, most travel in urban environments is work-related [4], so any attempt to make this type of travel more sustainable will achieve significant improvement ratios [34].

Teleworking, also known as telecommuting, is a way to perform one's professional activity remotely from a distance. This form of work, primarily concentrated among (white-collar) jobs with the operational flexibility to allow it, was developed in the 1980s [35,36], though the first studies adapted to a regulated and recognized form of work performance did not emerge until the 1990s [37]. [36] provide the most complete definition: "a flexible work arrangement whereby workers work in locations, remote from their central offices or production facilities, with no personal contact with co-workers, but the ability to communicate with co-workers using ICT".

COVID-19 brought about a paradigm shift in the labour markets of different world economies [38,39]. The paralysis of activity and suspension of mobility forced many organizations to implement the technology necessary to carry out activity remotely. Once the health crisis subsided, organizations consolidated the model, permitting much telework to remain permanent [1]. The cessation of activity and mobility restrictions caused a major reduction of mobility in all areas, both urban and interurban [40-42]. This reduction in the mobility of people and vehicles resulted in a drastic decline in greenhouse gas emission levels [43,44]. However, other studies claim that there was an increase in private car use as a result of COVID-19 for safety reasons; these studies predict that public transport use will return to pre-pandemic levels in the future [45].

Some of the existing literature suggests that telework potentially represents a chance to drastically reduce the number of trips, thus reducing traffic [10-12] but other studies suggest that the benefits of telecommuting are significantly less than anticipated [13].

With regard to the impact of telework on urban mobility, there is ample literature that strives to determine whether telework has a positive or limited impact on traffic. The first studies appeared back in the 1990s, when it was suggested that working from home would help cut traffic in urban areas by reducing the number of trips and distances for people working from home [46-49]. However, some contributions suggested that the aggregate travel impact will remain relatively flat in the future, even if telecommuting increased considerably [50]. In the last couple of decades, some studies have addressed the question

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of whether teleworking affects urban mobility positively, negatively, or in a limited way.

Several studies suggest that commute distance represents an important factor in travel behaviour. Commute distances for telecommuters, as an aggregate, are lower than distances for non-teleworkers, given the reduction in the number of commutes [16,51]. However, more recent research concludes that teleworkers, commute further on a weekly basis regardless of the fact that the number of commutes is reduced [52]. Telecommuting also increases total daily trip rates for both telecommuters and their households [53].

However, it is important to consider that telecommuting is a major factor in residential location decisions [54], meaning that the distances covered can be influenced by the household's decision since telework allows workers to move their homes further from the office, given the reduction of commute frequency. However, there is no clear evidence of the impact that telework may have on home location choice [55,56]. On the other hand, residence location may trigger the decision to telework [57]. [58] conclude that telecommuters tend to choose lifestyles involving longer one-way commutes, longer daily work trips, and longer daily non-work trips than non-telecommuters, as a result of the residential location being further from the office. In fact, teleworkers are willing to accept longer – albeit less frequent – commutes [21]. Telework may weaken the relationship between the current urban structure and travel patterns prompting a redrafting of the policies to adapt the urban structures to an increasingly widespread telework context [59].

It is important to point that the travel patterns shown by teleworkers are also studied based on the effect that telework has on both work trips and non-work trips. Teleworkers tend to cover further distances daily for non-work trips [18,60], and clock a higher number of non-work trips [13,61-64].

Teleworkers also show relevant patterns in relation to modal choice and its consequent impact on traffic. Some studies indicate that telework may allow a significant aggregated reduction of car use [10,65] in miles. In fact, telework may contribute both to the shifting away from automobile dependency to sustainable travel [66], to the use of active transport modes [12] and to the increased use of non-motorized travel [67,68]. Moreover, certain literature suggests that teleworkers modal choice patterns tend toward more pollutant transport modes [69], including cars [70]. The higher is the telework frequency, the higher the private car use [19].

The International Labor Office (ILO) classifies telework as three types; regular telework at home, highly mobile telework ("at several locations regularly, with a high level of mobility") and occasional telework ("at one or more locations outside the employer's premises only occasionally") [71]. But there are also studies that suggest distinct travel patterns based on two types of daily

telework: partial-day teleworking and full-day teleworking. Partial-day teleworkers significantly increase the number of trips and travel further while full-day teleworkers, on the days they engage in telework, make significantly fewer and shorter trips and are less likely to drive a car compared to those who do not telework [12]. [72], through a hazard model, determines that part-day teleworkers tend to commute during midday intervals avoiding peak-hours.

The majority of the literature agrees that it is possible to obtain positive results reducing peak-hour trips and vehicle miles travelled, through telework [11,20,68]. Avoiding peak-hours is directly correlated to flexibility at work. One of the main drivers for teleworkers is the possibility of avoiding peak traffic hours [73].

The literature review has been based on a comprehensive examination of the Web of Science database, where 53 articles have been identified as the most relevant to this question. Of the 53 articles, 44 of them, 83%, are studies based pre-Covid19 circumstances when the worldwide telework rate was far lower than post-Covid19. This means that there is lack of contributions in the current scenario where teleworking is much more prominent.

3 Methodology

Based on a review of the literature, since telework is understood as a measure that could improve traffic by reducing commutes, the data indicates the effect is limited or null. In this respect, this research aims to analyze how telework impacts urban traffic in the city of Madrid, according to the methodology described in this section.

First, we must determine the evolution of the telework rate over the years [5,24,29] and traffic occupancy in Madrid, using aggregated figures from the Madrid City Council database centre [74], and introducing timeframes to determine peak and off-peak times. This previous data organization allows the subsequent correlation and regression analysis to detect dependencies between telework and traffic occupancy in Madrid city.

Using regression analysis, we analyze the relationship between telework and Madrid traffic during peak times. The dependent variable, peak time traffic in Madrid, is denoted as Y , while the independent variable, telework implementation in Madrid is denoted X . There is always an accepted margin error since the variables will never correlate perfectly. The variation from the regression line can be split in two parts: explained variation, which is accounted for by the independent variable, and unexplained variation, which is not accounted for by the independent variable. Thus, part of the change in variable is due to another variable that we set as hypothesis, and part is due to other factors as indicated in the literature review.

In regression analysis, we seek to determine if the relationship pattern between two variable values can be described as a straight line (1), which is the simplest and most used form.

$$Y = a + bX \quad (1)$$

where:

Y is the dependent variable, measured in units of the dependent variable, X is the independent variable, measured in units of the independent variable, and a and b are constants defining the nature of the relationship between the variables X and Y.

a or Y-intercept (also known as Yint) represents the value of Y when X = 0.

b represents the incline of the line known as the regression coefficient and is the change in Y associated with a one-unit change in X. The greater the regression coefficient, the more influence the independent variable has on the dependent variable, and the more change in Y associated with a change in X.

The regression coefficient represents a good choice to check the effect of the telework variable to the traffic variable from a policy researcher perspective. To quantify the strength and direction of the relationship between two variables, we use the linear correlation coefficient (2):

$$r = \frac{\sum \frac{(x_i - \bar{x})(y_i - \bar{y})}{s_x s_y}}{n-1} \quad (2)$$

where:

\bar{x} and s_x are the sample mean and sample standard deviation of x, and \bar{y} and s_y are the mean and standard deviation of the y,

n is the sample size.

This statistic numerically describes how strong the straight-line or linear relationship is between the two variables and the direction, positive or negative.

ANOVA analysis is also used to partition the variation using sums of squares. The sums of squares and mean sums of squares are commonly presented in the regression analysis of variance table. The ratio of the mean sums of squares for the regression and mean sums of squares for error form an F-test statistic used to test the adequacy of the regression model. The relationship between these sums of squares is defined as follows:

$$\text{Total variation} = \text{Total variation explained} + \text{Unexplained variation}$$

The larger the explained variation, the better the model is at prediction. The larger the unexplained variation, the

worse the model is at prediction. A quantitative measure of the explanatory power of a model is R^2 , also known as the Coefficient of Determination (3):

$$R^2 = \frac{\text{Explained variation}}{\text{Total Variation}} \quad (3)$$

The Coefficient of Determination measures the percent variation in the response variable (y) that is explained by the model. Values range from 0 to 1. An R^2 close to zero would suggest a weak linear relation.

To complement the analysis, we have also applied Pearson's correlation coefficient given its representativeness and its use in relevant academic research on urban traffic [75,76] and telework [77]. We define the occupancy of the road as the dependant variable, with telework being the independent variable on this study.

4 Data analysis: telework and the effects on the traffic

4.1 Aggregated data analysis

Figure 1 shows the average traffic volume distribution for February 2020 in the city of Madrid, based on raw data published daily by the Madrid City Council using 7,360 vehicle detectors that count vehicles and determine the degree of urban road occupancy [74] to assess traffic distribution by the hour. Monday through Thursday were considered, as they are typical workdays in the city of Madrid and are homogeneous in terms of timetables. (Many organizations have specific schedules on Fridays; workers are often allowed to leave the office at lunchtime). Pre-COVID February 2020 was chosen to determine the baseline for traffic distribution in the city to set a threshold for the subsequent analysis, as it is important to understand former traffic patterns in order to measure the impact of a relevant increase in post-COVID19 telework.

The parameter used to observe traffic congestion is road occupancy from vehicles picked-up by traffic sensors. The road occupancy parameter indicates the percentage of time a traffic detector is occupied (by the vehicle) on average. For example, 50% occupancy in a 15-minute period means that the sensor has detected the given vehicles for 7 minutes and 30 seconds, on average [78].

Figure 2 shows the area of data collection where the sensors are distributed and captures the road occupancy that is targeted throughout this research.

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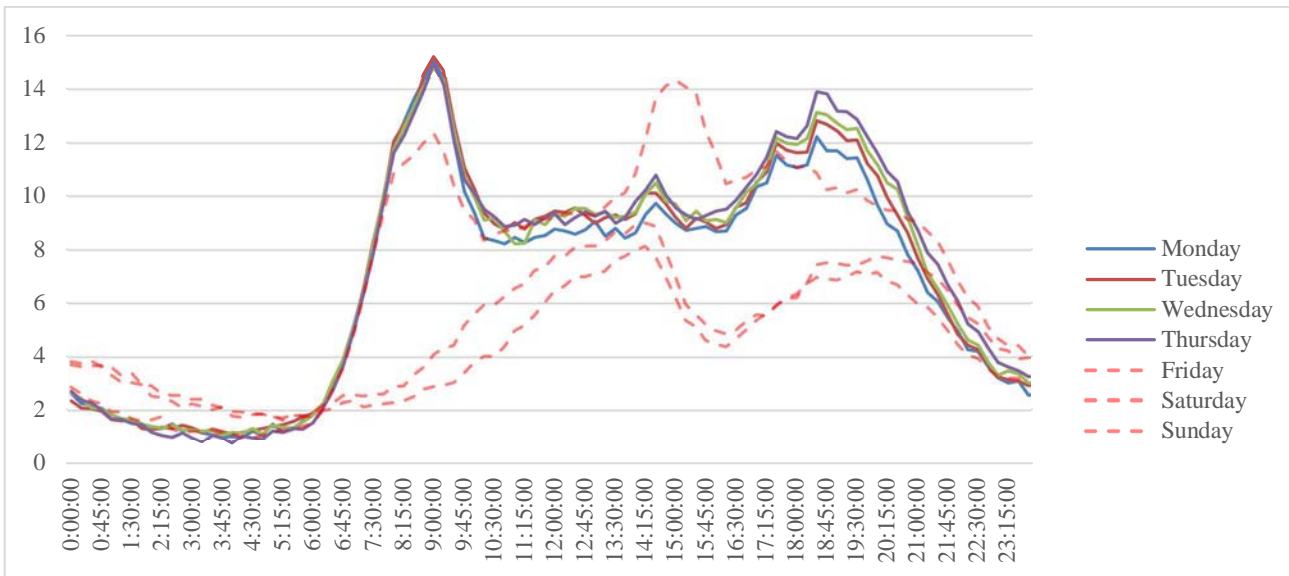


Figure 1 Daily traffic occupancy in Madrid urban areas (February 2020 aggregated mean) [73]

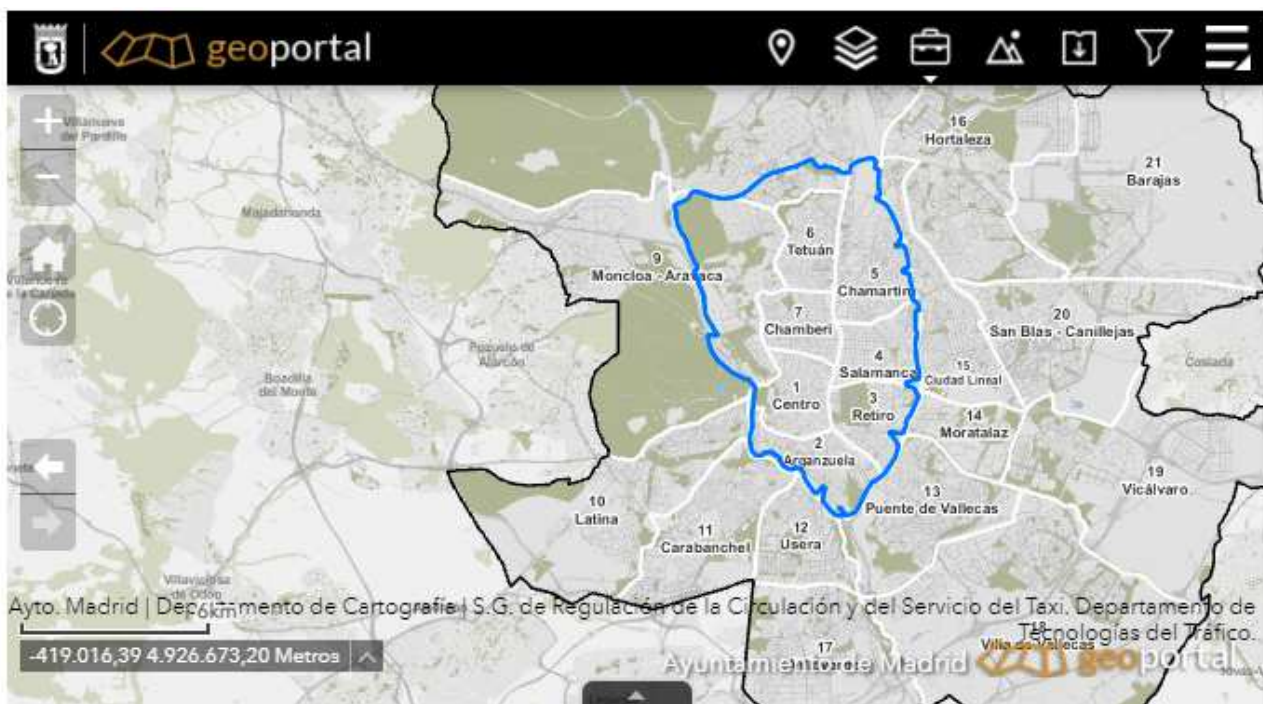


Figure 2 Area of data collection - Madrid (Spain) [79]

As illustrated in Figure 1, from Monday to Thursday, there is a concentration of traffic between 7:00 and 9:30 a.m. and between 6:00 and 8:00 p.m. These ranges correspond to the usual times for entering and leaving physical work. In other words, in a period of four and a half hours, there is a concentration of traffic due to work-related commutes in the city of Madrid.

Assuming that the 2.2 million private vehicle commutes are concentrated into these two 4.5-hour slots, and that at least 51% of the workers who can telework in Madrid [5,30] do so one day a week, Madrid would reduce

traffic by 43,000 vehicles per hour. This would, therefore, improve traffic flow, substantially decrease greenhouse gas emissions, enhance air quality, and minimize the many negative effects of pollution on the environment [80].

4.2 Impact of telework on Madrid traffic (pre-COVID vs. post-Covid)

Table 1 shows the rate of telework implemented in Madrid from January 2019 to September 2022 and the

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urban traffic occupancy recorded on a monthly basis according to the following assumptions:

- Traffic occupancy measured as monthly average from the recorded data [74]
- Peak-hours considered:
 - o From 7 a.m. to 10 a.m. Usual time of workplace arrival.
 - o From 5 p.m. to 8 p.m. Usual time of workplace departure.
- Weekdays considered: Monday to Thursday. Friday is excluded as timetables may differ in the Spanish market where employees are allowed to leave the office at lunchtime (from 2 to 3 p.m.)
- Holidays are excluded from the analysis
- Traffic road occupancy shown as monthly based on daily averages per the above conditions.
- 2020 is excluded from the analysis due to the impact of Covid19 and the restrictions followed by public authorities could distort the target metric.

Table 1 Occupancy and telecommuting evolution (aggregate daily peak time averages) [5,24,29,74,81]

Spot analysis		%Telecommuting	Urban traffic Load Peak
2019	Jan	8.30%	9.67
	Feb	8.30%	11.34
	Mar	8.30%	11.28
	Apr	8.30%	10.37
	May	8.30%	10.58
	Jun	8.30%	11.07
	Jul	8.30%	8.85
	Aug	8.30%	5.75
	Sep	8.30%	11.14
	Oct	8.30%	12.21

	Nov	8.30%	12.44
	Dec	8.30%	9.99
2021	Jan	27.80%	6.68
	Feb	27.80%	8.58
	Mar	27.80%	9.07
	Apr	25.80%	9.18
	May	25.80%	9.56
	Jun	25.80%	9.75
	Jul	22.10%	7.53
	Aug	22.10%	5.43
	Sep	22.10%	10.29
	Oct	21.50%	10.82
	Nov	21.50%	10.48
	Dec	21.50%	8.53
2022	Jan	23.20%	8.01
	Feb	23.20%	9.58
	Mar	22.10%	9.87
	Apr	22.10%	9.20
	May	22.10%	9.52
	Jun	22.10%	9.34
	Jul	22.10%	7.00
	Aug	22.10%	5.06

The figures shown in Table 1 contain the aggregate information from the original database to highlight the figures analyzed subsequently since each daily occupancy file contains more than 1 million rows.

Table 2 show the statistical analysis applied to understand the correlation between the rate of telework implemented and the impact on traffic during peak-times as suggested by the existing literature.

Table 2 Calculated values from statistical analysis (correlation/ANOVA)

SUMMARY OUTPUT	
Multiple R	0.335936893
R Square	0.112853596
Adjusted R Square	0.111252249
Standard Error	2.254346999
Observations	556

ANOVA

	Degrees of freedom	Sum of Squares	Mean Square	F-Value	Significance F
Regression	1	358.1553	358.1553	70.4741	3.913E-16
Residual	554	2815.4725	5.0820		
Total	555	3173.6278			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95.0%	Lower 95.0%	Upper 95.0%
Intercept	11.1924	0.2440	45.8626	9.09E-191	10.7131	11.6718	10.7131	11.6718
Teletwork %	-10.5952	1.2621	-8.3948	3.913E-16	-13.0743	-8.1161	-13.0743	-8.1161

Regression testing suggests a weak coefficient value of 0.3359. The closer the value is to 0, the more negative dependence there is between both variables. This result

suggests that telework does not have a strong impact on traffic in Madrid. In line with this result, according to the R Square that shows the value of the coefficient of

determination, the result obtained from the regression is 0.11 which represents an only 11% meaning that the strength of the linear relation between both variables is weak.

The standard deviation shows a low value indicating that the behavior of both variables is stable and consistent within this system.

The ANOVA test has also been considered taken into account to allow for the testing of the null hypothesis which considers that the model chosen to explain the dependency between telework and peak traffic is not adequate. An F

test is obtained to check this assumption. F-significance is close to 0 (3.91×10^{-16}) being lower than 0.05 (α -significance level). This means that null hypothesis can be rejected so that this model is correct in explaining the weak relationship between both variables.

Another index used to confirm the hypothesis that telework does not contribute significantly to traffic improvement during peak times is the Pearson correlation coefficient (4) between telework and peak traffic.

$$r = \frac{\sum(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum(x_i - \bar{x})^2 \sum(y_i - \bar{y})^2}} \quad (4)$$

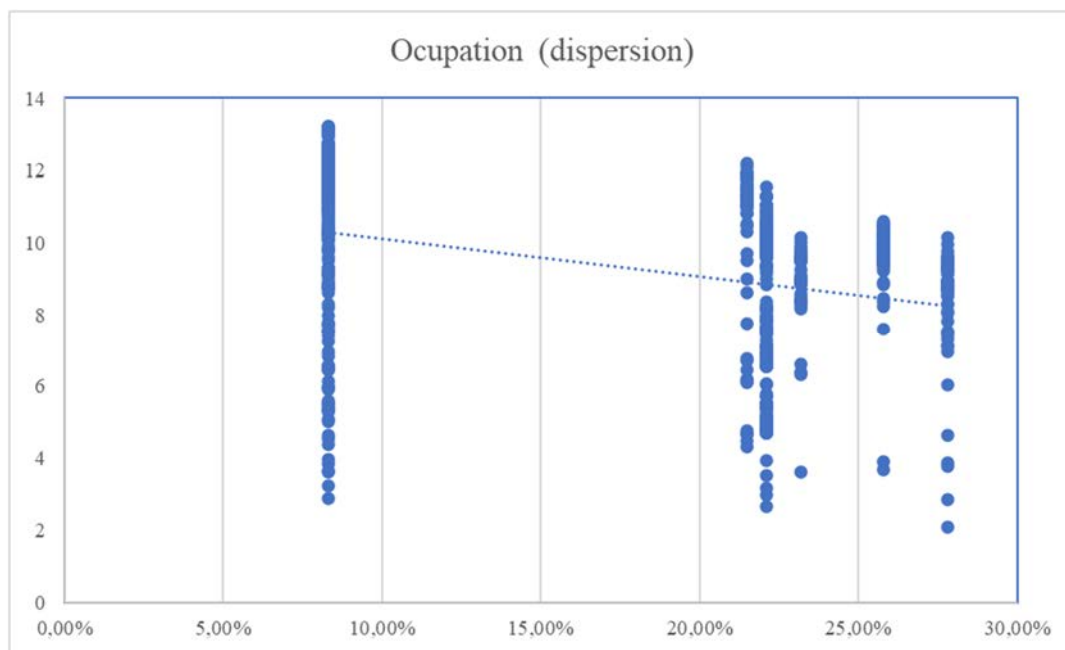


Figure 4 Pearson correlation coefficient – telecommuting/traffic occupancy ($p=0.05$)

Figure 4 shows the dispersion of the correlation between telecommuting and traffic occupancy where the correlation coefficient (r) is -0.33593 . The negative coefficient shows an inverse relationship between the two variables in such a way that when telework increases, traffic in Madrid decreases, but this correlation is limited given the value obtained as per Table 3.

Table 3 Pearson coefficient value interpretation

$r = 1$	Perfect correlation
$0.50 < r < 1$	High degree
$0.30 < r < 0.49$	Moderate degree
$0 < r < 0.29$	Low degree
$r = 0$	No correlation

These results confirm that the effect of telework on reducing traffic in Madrid is not so sensitive, suggesting that the decrease in traffic due to telework does not occur

in the same proportion, or at least in any significant proportion. This circumstance may thus indicate a presumed change in the pattern of consumer behaviour with regard to the modal choice on days when they must travel to work in person.

5 Conclusions

The result of our analysis leads us to conclude that, although telework reduces the number of trips in urban environments, the positive impact on traffic in the city of Madrid during peak times is limited, regardless of what is generally expected when eliminating commutes. The decrease in traffic in Madrid is not proportional to the increase in telework that is taking place. Three reasons may be behind this limited positive effect. First, COVID-19 still causes some misgivings about using public transport for health and hygiene reasons. Second, in the city of Madrid, out of the 22.1% of employees who work from home, 9.6% telework occasionally, that is less than 50% of the work

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week, meaning they commute to the workplace the remainder of the week. On these commutes a change in consumer behaviour may be occurring, such that consumers tend to opt for private cars. This change in consumer behaviour may be attributable to convenience, economic savings (on the transport fare), or an employee's willingness to incur higher transport costs by using a private car if commutes are limited to only a few days a week. Third, telework allows workers to make decisions about their place of residence in such a way that they can decouple this decision from the workplace, allowing them the possibility of residing in locations where the cost of living is lower. This influences people's mobility and transport as these locations are further away and have a more limited supply of public transport. This, in turn, causes an increase in the distances travelled and may favour the use of private vehicles.

The findings give rise to a set of implications for transport providers, given that telework influences mobility patterns and mode of transport choice. These implications suggest transport providers could implement a few lines of actions to adjust the transport infrastructure to the new context in urban areas, where the implementation of telework is widespread. Urban mobility constitutes a strategic element in terms of sustainability, given its impact on the carbon footprint. Therefore, any change in urban mobility patterns, as the results of this research suggest, must be considered to encourage public transport use, owing to its contribution to sustainable mobility [82]. Thus, it may involve the adaptation of both infrastructure and planning given the noted impact of telework on traffic.

At the same time, researchers suggest the need for further examination of the factors influencing mode of transport choice for people who work full- or part-time from home. Also, reducing traffic during peak times is a question that is more achievable through time flexibility at work to avoid commutes during peak times. The analysis carried out, though it attempts to refine the data obtained from the analysis of road use in the city of Madrid, still includes some journeys that are not for work purposes. Thus, this research highlights the need for further research, for the city of Madrid or others to provide a better understanding of the factors that influence the modal choice of consumers, through either quantitative or qualitative means given the evidence of the limited impact of telework on traffic.

Declaration of conflicts of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as potential conflicts of interest.

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The manuscript is based on the public information made available by the entities that have been cited herein. Database repositories are named in the reference lists.

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Evaluation of the efficiency of internet marketing in electronic business

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Abstract: The interactivity of information flows is becoming a major success factor and leading to significant changes in the field of e-business. The main purpose of the study is to evaluate the effectiveness of Internet marketing in e-business. It has been determined that ensuring business efficiency is inextricably linked with the use of Internet technologies in building communications with the target audience, logistics and supply chain management. The need for the introduction of Internet marketing in electronic business is highlighted to achieve and ensure efficiency, profitability and fulfillment of key KPI indicators. The method of economic and statistical analysis and evaluation of the effectiveness of Internet marketing in the context of e-business sectors in the world was applied. The key theoretical aspects of e-business development and its main directions are considered. The main indicators for evaluating the effectiveness of Internet marketing in e-business are identified, which allow determining the final structure of Internet marketing effectiveness indicators by industry. The organization of electronic business based on the proposed KPI indicators will provide a function to control the effectiveness of marketing, logistics, which is achieved by increasing conversion, reducing costs and improving competitive positions. A statistical analysis of world sales volumes in the field of e-business was carried out using Internet marketing tools. The results of the study, in contrast to existing approaches, made it possible to substantiate the need to apply in practice the formed methodology for the formation of KPI indicators their further control to ensure the effectiveness of Internet marketing.

1 Introduction

Business models and internal processes of modern companies are characterized by the fact that the exchange of information flows and business information, the implementation of operations and transactions are automated using information systems and technologies. A significant part of decisions in the field of organizing an effective business (from production to logistics), regardless of the segment of the world economy, is based on the use of modern Internet technologies. The presented technologies provide information flow and data management to provide various web services. Any types of commercial and non-commercial operations, including the exchange of information via the Internet, the organization of trade processes and the exchange of goods and services, their logistics between companies or groups of persons, are intensively developing within the framework of a new segment of the world economy - electronic business and individual industries in it (e-marketing, e-logistics and many others).

The organization of electronic business in modern realities cannot be imagined without the use of Internet marketing, which provides the entire cycle of organizing sales, interaction and communication with the target audience, logistics, service and support to ensure the effectiveness of the company's commercial activities. The introduction of a complex of Internet marketing in electronic business is associated with significant costs; therefore, the company's management is interested in the effectiveness of investments in marketing activities. However, in order to obtain objective information about

the effectiveness of Internet marketing in order to make management decisions based on it, it is necessary to comprehensively evaluate the effectiveness of marketing activities in e-business in the context of industries and segments.

Ensuring the effectiveness of e-business, e-logistics and information flow management is inextricably linked with the use of Internet marketing tools, which is characterized by the formation of a whole range of activities for interaction and communication with the target audience throughout the entire life cycle of the company: from production, sales, service, maintenance and logistics. The identified issues are relevant and in demand in the modern world for the formation of theoretical and practical aspects of organizing e-business and evaluating its effectiveness, which is ensured by the use of an Internet marketing strategy. The development of the theory of e-business organization in connection with the implementation of the Internet marketing strategy and the development of a methodology for evaluating the effectiveness of Internet marketing are a necessary and relevant topic and require deeper research.

1.1 The main directions and features of the development of electronic business

The historical development of electronic business begins in the 20th and 21st centuries, when a unified information system of the planet was created. If earlier the resources of economic development were quite rigidly tied to territories and technologies, now the main resource is information, which largely contributed to the development

of the Internet. Since the early 1990s, the spread of information and communication technologies has taken on an all-encompassing scale, and the speed of their spread has exceeded all expectations. At present, there is no sphere of human activity that would not undergo significant changes due to the massive introduction of modern information and communication technologies. The term "e-business" the IBM Marketing and Internet group coined it in 1996. Commercial use of the Internet was prohibited until 1990, but as a result, e-business could not reach its full potential. Significant to the intensity of the development of e-business is that in the 1990s, the first large private corporations received permission to operate on the Internet, and the control of the Internet, which was previously under the complete control of the US government, was transferred to private individuals. After that, in 1992, the commercialization of the Internet received the approval of the US Congress, and from that moment, the e-business market entered a new phase of its development. In 1993, the electronic money technologies of the future were invented, and in 1994, the first electronic payment system appeared on the Internet. In 1995, the Amazon online store site was opened, which is today the largest online store in the world, and at the same time, the first online bank began to operate. It should be noted that the first online stores, in fact, conducted electronic business using the long-established technology of trading by telephone and mail, which at that time was widespread in the United States [1-2].

After this stage of development of e-business, the first business models related to the B2C category appeared. The primary mechanism of Mail Order - Telephone Order was transferred to the Internet environment, which was an order for a product or service by filling out a form on the seller's website, payment was made by a plastic card, delivery of goods was carried out by mail or through a courier service. This direction includes any type of business focused on the end consumer: online stores, banking services for individuals via the Internet, online auctions, online education, paid advertising on the Internet and much more. At the same time, electronic business between individuals, C2C, is gaining momentum. A striking example is Internet auctions, consulting services between individuals via the Internet; various exchange platforms, and tutoring via the Internet. On the verge between C2C and B2C, there are websites of freelancers (photographers, make-up artists, cosmetologists), which, in fact, are online stores selling services to individuals [3].

A qualitative leap in the development of e-business, e-markets, e-logistics occurred when the desire to expand distribution channels led to the B2B sales network. In principle, anything can be the subject of commerce here, but the main prospects for B2B are in the service sector. It is currently the largest and fastest growing e-business sector. Electronic business in the field of B2G, in fact, is similar to B2B; only the customer in this case is the state. The main example of this type of interaction can be public

procurement conducted via the Internet, sociological and marketing research for government agencies, various social advertising on the Internet, placed by order of government agencies and aimed at preserving the physical and spiritual health of the nation [4].

E-business is a cumulative concept for many classes of information systems that are aimed at automating the commercial work of excellent companies and organizations, regardless of segment, type of activity and geography. It is very important to emphasize that e-business, which is focused on interaction with the consumer in the field of sales, is supported by the entire value chain from production, sale of services to logistics and support. At the present stage, the leaders of the world economic and political space are precisely those countries that have learned to determine the vector of development of information technologies and the effective management of information flows, use new opportunities for their application and popularization in all areas of activity. It is well known that the global industry of information and telecommunication technologies is one of the most dynamically developing sectors of the world economy. The information sphere has become the locomotive of the economic development of many countries. It is no coincidence that relatively recently such concepts as e-business and e-commerce, e-logistics and e-economy have appeared in the economic environment.

Electronic business in the modern world is any business activity that uses the capabilities of global information networks to transform the company's internal and external communications in order to increase profits. In accordance with UN standards, a business is recognized as electronic if two of the four components (production of a product or service, generation of demand, delivery and logistics to the consumer, and payment) are carried out using the Internet. E-business is considered to include sales, marketing, financial analysis, payments, employee search, e-logistics, user support, and partner support. Electronic business is a form of doing business, in which a significant part of it is carried out using information technologies (local and global networks, specialized software, etc.).

Thus, the relationship between the concepts of "electronic business" and "electronic commerce" should be considered as inseparable parts of the whole, since these terms are often used interchangeably. In the first case, electronic business consists of such structural components as: electronic commerce (electronic commerce); electronic private procurement (e-procurement); electronic public procurement (e-government); electronic customer service (e-care for customers); e-care for business partners (e-care for Business Partners); e-logistics and e-care for employees; e-care of influencers. In the second case, the participants between whom there are commercial relations [3-4] determine electronic business. The structure of e-business depending on the participants is shown in Figure 1.

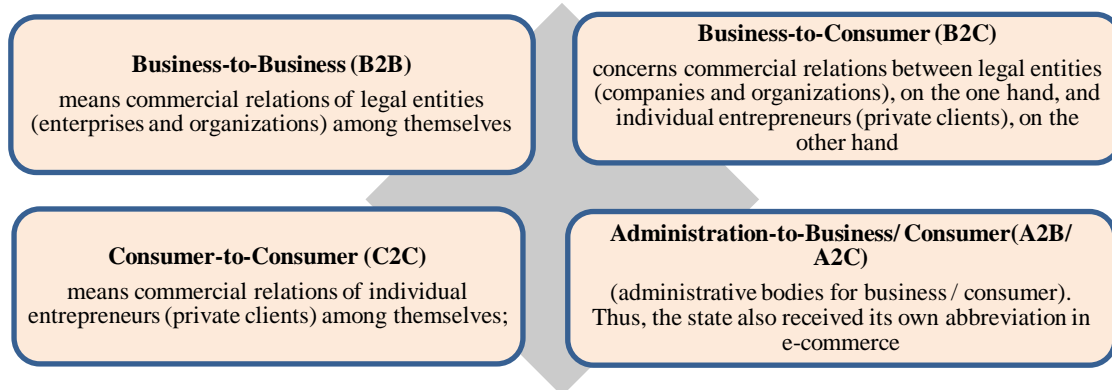


Figure 1 The structure of e-business depending on the participants

E-business is characterized by the fact that companies of a certain type, which operate on the basis of Internet technologies, are concentrated in this area of activity. This type of business is aimed at servicing the digital flow of products, and the full cycle of the transaction includes all stages from production, sale, delivery, service, support, service and everything is based on Internet technologies [5].

This type of business is dependent on innovation and the use of information technology, and the organization of the sales, communication and service process is impossible without the use of a marketing strategy that is inseparable from the Internet. The effectiveness of e-business is ensured by a rational strategy of Internet marketing, which includes all the necessary components and elements that are necessary to achieve the main goals of companies.

1.2 The relationship of e-business and Internet marketing

E-business is a sphere of active emergence and use of innovations, information and telecommunication technologies, which can be effectively organized by building a development strategy based on Internet marketing. The relevance and necessity of this study is confirmed by the presence of a large number of studies in this area, which contributes to further research and development of this direction.

The process of organizing an e-business should have an integrated approach and include all key stages from the production of goods and services to their sale, promotion, communication with customers and further service, logistics, which can be achieved through marketing. Marketing activity is a controlled and multifaceted process that is aimed at meeting the needs of potential and real consumers of the company's products, which consists in the implementation of not only specific marketing functions, but also the setting of specific goals, ways to achieve them and sources of resources for commercial activities in general.

When organizing an e-business, it is important to use a marketing strategy based on the same technologies and approaches, i.e. on the Internet, which will ensure the

effectiveness of e-business by rationally defining the main stages and tools to achieve the main goal. An e-business marketing strategy provides control and management of the marketing activities of a company's goods and services using various tools such as target audience analysis and research, market research, promotion, advertising, maintenance and service, e-logistics, and more. Depending on the evolution of marketing and its areas of application, the nature of demand in the market for goods and services, such characteristics of marketing as types, forms and types of marketing are distinguished. Types, forms and types of marketing directly depend on the tools that are used in the promotion. It is possible to conduct an electronic business focused on Internet technologies, but without an Internet marketing strategy, its development is impossible. Since e-business is characterized by the use of Internet technologies, the effectiveness of which is possible with the help of Internet marketing, its tools should be considered:

- Content marketing, which includes podcasts, blogs, link baiting, guest posts, video creation, webinars.
- Email marketing, which includes lead magnets, segmentation, split testing and email automation.
- Search engine optimization (SEO), which consists of keyword research, search engine optimization of website pages (internal optimization), external optimization, technical SEO.
- Conversion optimization consisting of conversion focused web design, headline optimization, calls to action (CTA), social proof; A/B testing (UI and UX elements), targeted advertising.
- Social media, which include advertising in instant messengers and social networks, choosing the optimal channel, social listening (monitoring social media).
- Paid advertising: - retargeting (remarketing), which includes the following activities: Google AdWords, advertising on YouTube, advertising on social networks, purchasing programmatic advertising (programmatic advertising).
- Free online marketing tools, which include free website and online store builders, free personal blogging services, social networks, forums, message boards, free

email services, online instant messaging services, directories and free services for posting information about goods and services, Q&A services, thematic portals for free publication of ads, online auctions, sites selling goods.

- Leads and lead generation, which are aimed at: personal interaction, attracting leads via the Internet. Newsletters (e-mail, SMS, etc.).

- Viral marketing, consisting of banner and teaser advertising.

- Video marketing, which is based on the type of content and its promotion among the audience.

- Guerrilla marketing, which is aimed at developing cooperation with companies, advertising and holding a shocking action, the natural introduction of goods into the lives of ordinary people using front men who play the role of happy buyers.

- Non-standard marketing, which includes the following types and areas: Crazy PR, Storytelling and many other innovative areas.

- Electronic logistics, which ensures the finalization of the marketing process and the delivery of orders and purchases to consumers. The organization of this process at an effective level will improve supply chains and management of logistics information flows.

The described Internet marketing tools are directly involved in the process of organizing an electronic business and are an inseparable part to ensure its effectiveness, depending on the type of activity and audience segment. To ensure the effectiveness of Internet marketing in e-business, which is based on the promotion of goods and services and the retention of the target audience, develop marketing strategies and policies that include the tact to achieve the goals.

1.3 Review of scientific literature in the field of evaluating the effectiveness of Internet marketing in e-business

The intensity of the development of information and telecommunication technologies and the need to manage information flows encourage many managers of modern companies to change their approaches to organizing activities and actively carry out marketing intra-organizational changes, research on the external environment, which can be carried out based on an effective organization. E-business, which is supported by an Internet marketing strategy.

The relevance of improving the efficiency of modern companies in the e-business segment is due to the need to search for and organize a business using an Internet marketing strategy that will ensure the implementation of strategic plans. To highlight the main directions in the field of the theory of evaluating the effectiveness of Internet marketing in e-business, it is necessary to consider the existing approaches in the scientific works of scientists.

Assel G. [6] emphasizes the need for constant evaluation based on an analysis of the volume of production costs and their impact on the volume of

products sold in the framework of the effectiveness of marketing activities. This approach also takes place in modern conditions of organizing the activities of manufacturing companies, taking into account small improvements and expanding factors for analysis, taking into account the specifics of the company's activities. In the work of L. Balabanova [7], it is proposed to evaluate the effectiveness based on the evaluation of the following areas: procurement, marketing integration, information adequacy, strategic focus, operational efficiency. It is important to state that this approach does not define a system of indicators for organizing the assessment process and requires serious improvements and modernization of the methodology itself, which requires further research and development in this area.

Anfinogenova Yu. [8] when determining the effectiveness of marketing, groups of indicators are distinguished based on the ratio of marketing costs and profits or sales volumes: profitability index (the share of reduced profit from marketing activities to reduced costs); market share of the organization; dynamics of margin and profit; dynamics of sales volume, which is a direct reflection of the effectiveness of marketing activities; reaching the breakeven point. It is important to note that this approach is aimed at a detailed analysis of the main key items of expenses and income, which does not take into account unplanned expenses that may arise under the influence of various factors, which should be improved in this methodology to meet its modern realities.

Kotler F. [9] focuses on the need to assess the relationship between marketing performance indicators and factors of the external and internal environment. This approach is relevant and in demand in modern business, however, no specific methodology has been proposed that would rationally evaluate the entire marketing process from production to sales and logistics, which requires a more detailed study and improvement of this approach, taking into account modern business conditions. Yasheva G. [10] emphasizes that the priority is the evaluation of economic efficiency, and not the marketing activity itself. It is important to state that although this approach considers marketing expenses only as an operating expense (and not as an investment) and does not include all cycles of the marketing process. This approach has become a logical starting point for evaluating the effectiveness of marketing activities through the analysis of the return on investment of marketing investments, which is currently widely used by Western companies, is gaining popularity and is being further developed.

In her study, Moiseeva M. [11] provides indicators of marketing activities by function (market research, assortment policy, marketing activities, communication activities) and general indicators (profitability, strategic activities). However, it should be emphasized that the issue of evaluating the effectiveness of Internet marketing in e-business remains open and requires detailed research. Tull, Donald S. [12] argues that an empirical approach is better

than a quantitative approach based on statistical testing of narrow deductive hypotheses. The paper presents the results of a study conducted in the early 90s in England, some European countries and the USA [13]. This approach is a classic and does not meet modern trends and features of e-business organization, which requires a more detailed study. Based on a review of scientific literature and research in terms of evaluating the effectiveness of Internet marketing and its effectiveness, it should be stated that the effectiveness of marketing was analyzed in the following areas: the internal attitude of the company's management to marketing (its definition, roles and functions); organization of this activity (involvement in the strategic planning process, level of coordination and information exchange between marketing functions) practical implementation of marketing functions (use of marketing research, planning, participation in the development of new products and organization of an effective logistics process, etc.).

The considered main studies in the scientific literature in the field of evaluating the effectiveness of Internet marketing in e-business allow us to conclude that there is no single approach to evaluating the effectiveness, which should be formed based on the selected approaches and requires improvement and more detailed study. The need

to develop a methodology for evaluating the effectiveness of Internet marketing in e-business determines the relevance of this study and its practical significance. Based on the generalization of the reviewed scientific literature; it should be argued that the process of evaluating the effectiveness of Internet marketing should be carried out on the basis of the following steps and procedures:

- 1) Determination of the purpose of the process of evaluating the effectiveness of Internet marketing.
- 2) Collection of statistical information and formation of a base of KPI indicators for a comprehensive assessment of the entire marketing process from production to logistics.
- 3) Analytical analysis of information flows and calculation of KPI indicators.
- 4) Substantiation of initial values and methodology for qualitative assessment of calculation results.
- 5) Formation of economic conclusions and development of projects of management decisions [14-16].

To substantiate the main KPI indicators for evaluating the effectiveness of Internet marketing in e-business, it should be noted that these indicators should take into account the strategically important factors of influence in modern business conditions, both internal and external, which is shown in Figure 2.

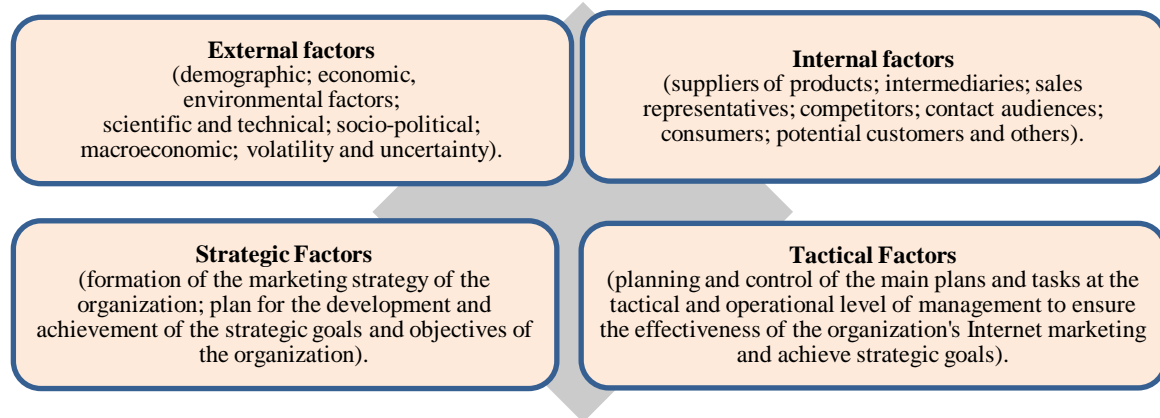


Figure 2 Factors influencing the effectiveness of Internet marketing in e-business

Internet marketing in electronic business is aimed at solving such issues as studying the tastes and preferences of the consumer, researching competitors, searching for distribution channels, analyzing the volume of product distribution for companies, creating new products, researching and working on an advertising campaign [17].

Modern trends in the organization of e-business are characterized by the fact that the use of a standard set of marketing is not enough to ensure the effectiveness of activities, which causes organizations and companies to move to a new era of marketing - Internet marketing.

The development of innovative technologies and their implementation and use in the e-business sectors of the economy makes it possible to optimize the cost structure for standard marketing mixes of an organization and

determines the use of Internet marketing tools to ensure the efficiency of companies and achieve strategic goals.

2 Methodology

2.1 Peer review process

E-business is aimed at the integrated automation of the commercial work of companies and organizations, which is focused on interaction with the consumer in the field of sales and support for the entire chain of the sales and logistics process. Strengthening competition and the generation of instability by the crisis processes of the world economy strengthens the role and necessity of using marketing in the activities of economic entities. The growth of uncertainty, both external and internal, puts in the first place for many companies the issue of ensuring the

effectiveness of activities, taking into account the presented factors. The effectiveness of many companies is characterized not only by making a profit, but also by strengthening planning, monitoring economic programs, qualitative risk assessment, using existing systemic methods for managing information flows, and solving various marketing and logistics problems.

A review of scientific literature in the field of evaluating the effectiveness of Internet marketing in e-business, indicating the presence of a problem that consists in the lack of a unified approach to developing a methodology for evaluating the effectiveness of Internet marketing in e-business, followed by the definition of key indicators and their elements that would take into account the influence of all factors through the use of innovative Internet tools and methods. The informatization of society and the intensive development of electronic business are characterized by the fact that the organization of this business, taking into account all factors, is impossible without the implementation of an Internet marketing strategy.

However, the use of Internet technologies is relevant in the modern world, which in turn leads to the modernization and improvement of existing methods, mechanisms, concepts and management strategies, marketing and its application in electronic business are no exception, which indicates the need for further research. Since in modern marketing there is no single approach to evaluating the effectiveness of Internet marketing, there is a conceptual need and relevance for the development of methodological foundations for their evaluation and a deeper study, which was carried out and reflected in the main results of this article.

The key goal of the study is to evaluate the effectiveness of Internet marketing in e-business. In accordance with the purpose of the study, the following tasks were defined: analysis of the theory of Internet marketing and the elements contained in it; classification of existing Internet marketing tools in terms of their effectiveness; classification of KRI indicators for evaluating the effectiveness of Internet marketing in electronic business; formation of recommendations for improving Internet marketing in modern conditions. To achieve the goal of the study and the implementation of the tasks set, general scientific and private research methods were used.

Analysis and synthesis of key areas that are used to evaluate the effectiveness of Internet marketing in e-business; process and system approaches - to develop a key algorithm for evaluating the effectiveness of Internet marketing in electronic business; economic and statistical analysis of KPI indicators for the effectiveness of Internet marketing in e-business and their grouping depending on the type of activity; graphical method and method of constructing analytical tables - for visual interpretation of the main results of the methodology for evaluating the effectiveness of Internet marketing in electronic business.

The proposed method for evaluating the effectiveness of Internet marketing, taking into account the formed and certain factors, can be applied in the practical activities of modern companies. The developed methodology will highlight the strengths and weaknesses of the Internet marketing strategy of modern companies with its further adjustment to achieve strategic business goals and ensure the effectiveness of e-business in general.

3 Result and discussion

When organizing an e-business, which is based on an Internet marketing strategy, success largely depends, as a rule, on the achievement of specific results, such as: profit growth, the number of calls, clicks, goods or services sold, as well as the quality of supply chain management. However, the choice of communication channels with the client at the planning stage will require an assessment of effectiveness even before making changes to the marketing. Brand promotion on the Internet is a complex and costly process, as competition in commercial segments is growing every day. It is definitely possible to calculate the ratio of profits and investments, but this is not enough for a complete picture. To evaluate the effectiveness of online marketing in e-business, several tools are used, and each of them has its own metrics by which you can evaluate the effectiveness. The main KPIs of the effectiveness of Internet marketing companies in e-business are presented in Table 1.

Therefore, the vector of marketing strategies is shifting towards individual work with the consumer. Communication based on mutual interest is today the leading direction of Internet marketing in e-business. Modern marketing tools allow you to conduct a deep analysis of the target audience, its preferences, and requests and determine the need for the introduction and launch of a particular product or service. These tools allow you to create a profile of each client in order to build the most appropriate interaction scheme with him. This approach leads to optimization of marketing budgets, expansion of the client base and sales growth by studying your audience and choosing the most accurate message when organizing an e-business.

The organization of an electronic business based on an Internet marketing strategy is based on a combination of several tools, each of which requires costs and investments. Different tools can bring different results and value depending on the niche and segment being used. Evaluation of the effectiveness of Internet marketing may vary depending on what goals the company's management pursued in the e-business segment. To evaluate the effectiveness of Internet marketing in e-business, it is necessary to use various labels and markers [18].

To substantiate the described hypotheses and the theory of this study, it is necessary to evaluate the effectiveness of Internet marketing in electronic business. The functioning of e-business in the context of Internet marketing is

inextricably linked with the use of innovative technologies and tools that allow you to optimize the main business processes of companies and improve your work. Many

world-class companies use innovative tools to evaluate the effectiveness of Internet marketing in e-business, one of which is Google Analytics [19].

Table 1 The main KPI indicators of the effectiveness of Internet marketing companies in e-business

KPI indicator	Features of the methodology for evaluating the effectiveness and characteristics
Conversion Rate (CR)	Displays the number of visits that ended with the target action (registration, purchase) to the total number of visits. CR allows you to evaluate the effectiveness of a given marketing channel.
Bounce Rate (BR)	Displays the number of users who left the site after viewing only 1 page. If the Bounce Rate is more than 40%, this is a serious reason to reconsider the approach to organizing this element of the organization's Internet marketing.
Average Order Value (AOV)	This indicator allows you to compare in retrospect the performance indicators of the Internet marketing tool in terms of the amount of income generated.
Cost Per Click (CPC)	The ratio of spending on an advertising campaign to the number of clicks. Allows you to evaluate the effectiveness of using contextual advertising placed on paid sites.
Cost Per Order (CPO)	Displays the cost effectiveness of attracting one client through the use of Internet marketing tools
Return Of Investments (ROI)	An indicator of the effectiveness of Internet marketing tools and return on investment.
Return Of Marketing Investments (ROMI)	The main indicator of the effectiveness of Internet marketing. Shows the return on investment in marketing.

Also, special attention should be paid to such Internet marketing tools in e-business as search engine optimization and contextual advertising, which provide increased customer loyalty, brand awareness and promotion, which generates an increase in income from this type of

marketing, which is reflected in the indicators (AOV,%) and (CPC,%).

The structure of Internet marketing performance indicators in the electronic business of world companies by industry as of 01.01.2022, in %, is presented in Table 2.

Table 2 The structure of Internet marketing performance indicators in the electronic business of world companies by industry as of 01.01.2022, in %

Conversion Rate (CR, %)		Average Order Value (AOV, %)	
Tourism	25.10%	Baby food and toys	189.35%
Real estate	11.20%	Vehicles	130.93%
Business consulting	27.40%	Clothing and accessories	117.51%
Business services	15.70%	Food	113.92%
Lending	24.30%	Sport and relaxation	94.15%
Healthcare	12.30%	Animal care	80.11%
Higher education	11.50%	House and garden	76.55%
Building	14.90%	Art and graffiti	76.49%
The legislative framework	15.40%	Agricultural goods	63.95%
Professional education	25.00%	Electronics	60.39%
Sport	11.00%	Appliances	55.61%
Electronics	12.00%	Healthcare	37.96%
Cost Per Order (CPO, %)		Bounce Rate (BR, %)	
Laws and Government	86.49%	Art and entertainment	58.85%
Vehicles	49.37%	Vehicles	48.30%
Business and Manufacturing	38.54%	Beauty and fitness	57.31%
Beauty and fitness	71.88%	Books and literature	63.41%
Personnel and Management	43.90%	Business and Manufacturing	56.41%
Education	80.00%	Finance	57.92%
Finance	41.14%	Food	59.36%
Insurance	48.05%	Hobbies and entertainment	55.53%
Healthcare	31.96%	Internet and television	58.53%
Repair work	68.12%	Work and education	54.07%
Sport	61.22%	Electronics	29.23%

This tool is a service developed by Google to generate detailed statistics on marketing activities. A feature of the service is that the webmaster allows you to calculate the ROI and the effectiveness of marketing expenses. This tool

allows you to evaluate not all indicators, which does not give a reliable picture, and for their detailed calculation and evaluation, many settings and personalization approaches to the description of indicators are required.

Evaluation of the efficiency of internet marketing in electronic business
Mahmud Agel Abu Dalbough

This tool is one of the most used and allows you to control the effectiveness of Internet marketing in e-business and understand how certain tools affect the company's efficiency in the e-business segment.

The presented structure of the main performance indicators of Internet marketing companies in the electronic business allows us to determine that using innovative Internet technologies for promoting goods and services such as: a website, corporate pages on social networks, advertising, which indicates a high percentage of conversion (CR,%) and the number of visits (BR,%) in the sectors: business consulting, vocational training, tourism and lending, politics, legislation, finance and insurance, the necessary level of marketing efficiency is provided.

It should be noted that in order to use innovative tools and Internet technologies in marketing, it is necessary to spend quite large amounts of investments, and their

effectiveness ensures the achievement of the strategic goals of the organization. The effectiveness of e-business directly depends on the Internet marketing tools used to achieve all the company's strategic goals. The assessment of the effectiveness of Internet marketing of companies in the world in the context of industries as of 01.01.2022 determines the need for more intensive development of Internet marketing as a key tool for ensuring the effectiveness of e-business. The functioning of Internet marketing and its application in electronic business is gaining more and more widespread use in all industries. Since, the main indicators of the effectiveness of Internet marketing are the payback of the funds spent on marketing activities and the number of customers attracted to the company. The cost structure for Internet marketing tools and their effectiveness in global e-business companies by industry as of 01.01.2022 in % is presented in Table 3.

Table 3 Structure of costs for Internet marketing tools and their effectiveness in global e-business companies by industry as of 01.01.2022 in %

Cost Per Click (CPC, USD)		Return Of Investments (ROI, %)		The effectiveness of Internet marketing tools (ROMI, %)	
Clothing	\$0.45	Electronics	60.60%	Laws and Government	70.30%
Vehicles	\$2.24	Vehicles	52.40%	Search contextual advertising	29.30%
Business and Manufacturing	\$2.52	Business and Manufacturing	45.50%	Display Advertising	6%
Beauty and fitness	\$1.81	Finance / Insurance	69.70%	Social Media Postings	5.10%
Business consulting	\$3.08	Business and Manufacturing	38.90%	Targeted advertising	14.90%
Education	\$1.06	Healthcare	37.90%	Email marketing	6.50%
Electronic logistics	\$2.72	Electronic logistics	36.40%	Insurance	10.10%
Finance/ Insurance	\$5.77	Education	35.30%	Healthcare	5.00%

The effective use of Internet marketing allows you to increase profits by promoting and increasing consumer loyalty, which in turn provides a competitive position in the market, increasing conversions and optimizing costs. The organization of e-business is impossible without the use of innovative mechanisms and management tools, and this also applies to marketing. Since e-business is based on Internet technologies and work organization approaches, it cannot be imagined without an Internet marketing strategy that distributes all the necessary steps, tools and their

implementation into activities depending on the industry and type of activity [20]. The effectiveness of Internet marketing in e-business is ensured by an increase in the volume of conversion through the use of certain tools. The dynamics of sales in electronic business, which are provided with the help of Internet marketing in trillion. USD, as well as the growth rate compared to the previous year in % for the period from 01.01.2017 to 01.01.2022, are shown in Figure 2.

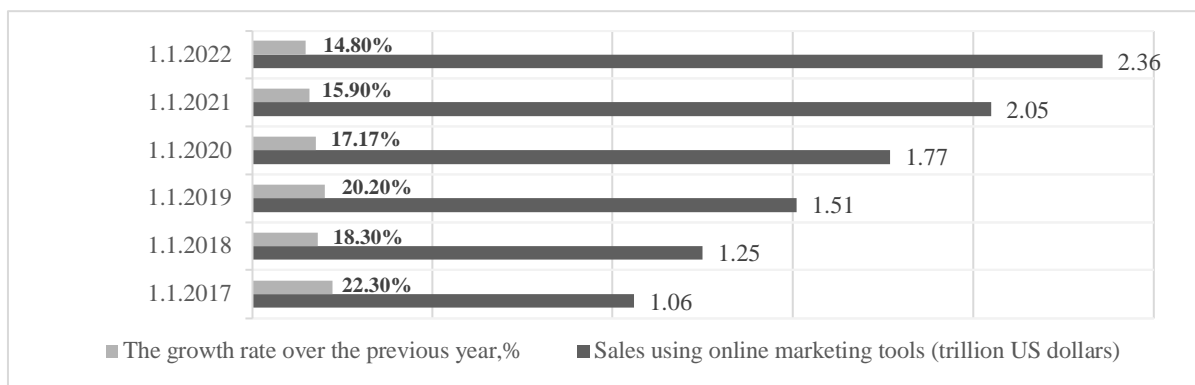


Figure 3 The dynamics of sales in electronic business. which are provided with the help of Internet marketing in trillion. USD USA. as well as growth rates to the previous year in % for the period from 01.01.2017-01.01.2022

The presented dynamics of sales volumes in electronic business, which are provided with the help of Internet marketing, increase every year, which indicates an increase in interest in the effectiveness of Internet marketing by the management of world companies, which is also confirmed by the growth rate compared to the previous year in %. From the results obtained, the hypothesis of the need for constant evaluation and monitoring of performance indicators is confirmed, which will allow planning both at the operational and tactical levels the company's marketing strategy in electronic business. Since evaluating the effectiveness of each tool allows you to identify priority areas and weed out frankly weak and ineffective ones.

4 Conclusions

The intensity of the development of innovative technologies and their implementation in modern business segments requires constant improvement of management approaches and methods. The study is aimed at studying the existing scientific approaches to evaluating the effectiveness of modern Internet marketing, which is an integral part of electronic business. The emergence and rapid development of the global Internet has led to a real revolution in the organization and conduct of business. The transformations affected both the external relations between companies and their partners or customers, as well as the internal structure companies. Not only new areas of doing business (trading platforms, auctions, electronic markets, e-commerce and others), but the existing strategies for conducting and organizing activities have changed radically.

The main results of the study made it possible to achieve the set goal, which concerned evaluating the effectiveness of Internet marketing in e-business. Scientific approaches and theories of development of key aspects of the development of e-business in the world are considered. This made it possible to focus on the intensity of the development and implementation of information and telecommunication technologies in all spheres of human life, and also made it possible to argue for the lack of a unified approach and methodology for evaluating the effectiveness of Internet marketing, which led to the relevance and need for a detailed study. Based on the presented, the author carried out a deep analysis of existing scientific approaches and theoretical aspects to the development and establishment of e-business, identified the main types and forms of e-business, depending on the participants in modern conditions.

The peculiarity of the organization of electronic business, which is inextricably linked with the introduction of information technologies into the global business industry, is considered, where the need to use marketing as an element of management and strategy is highlighted. Since e-business is based on Internet technologies, then marketing must correspond to this. In the article, the author argues the inextricable link between e-business, e-logistics, e-commerce and Internet marketing, the use of which in

combination ensures the effectiveness of existing processes.

Due to the lack of a unified approach in the scientific literature to determine the methodology and tools for evaluating the effectiveness of Internet marketing companies in electronic business, a study of approaches was conducted and an approach to evaluating the effectiveness of Internet marketing was formed.

KRI indicators have been selected to assess the effectiveness of online marketing of companies in electronic business, depending on key influencing factors and strategic goals. To substantiate the methodology for evaluating the effectiveness of KPI, the key tools of Internet marketing of e-business companies were identified, which made it possible to determine the need for their use in the framework of achieving and ensuring the achievement of target business indicators and tasks. It is argued that, taking into account current trends in the implementation of innovative technologies and approaches to doing business on the Internet, it is necessary to use existing Google Analytics tools to evaluate the effectiveness of Internet marketing and obtain reliable results.

A methodology for evaluating the effectiveness of online marketing of e-business companies based on key KPI indicators of global companies by industry has been formed, which made it possible to determine the most rational and effective tools, as well as profitable e-business industries. Based on the sorted methodological approaches, the author assessed the effectiveness and considered the dynamics of sales of electronic business using Internet marketing tools for the period from 01.01.2017 to 01.01.2022.

The presented allowed us to formulate the main hypotheses and confirm them in terms of the fact that in order to ensure the effectiveness of Internet marketing in electronic business, it is necessary to use innovative methods and Internet technologies to achieve strategic goals.

The results of the study, in contrast to existing approaches, made it possible to substantiate the need to apply in practice the formed methodology for the formation of KPI indicators and their further control to ensure the effectiveness of Internet marketing.

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Review process

Single-blind peer review process.

Increasing the efficiency of warehouse analysis using artificial intelligence

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Keywords: artificial intelligence, artificial neural network, warehousing, ABC XYZ analysis, black hole algorithm.

Abstract: Logistics in companies is a necessary process that has high costs with mostly no added value. Lowering this cost is vitally important for companies to stay competitive. Nowadays, storage systems are a critical part of any company's logistic system, and many of them try to reach an optimum level where they can operate with little freedom of movement of goods declared by the changing market. There are several manual and automated methods to achieve this. However, we hear quite little about the use of artificial intelligence in the field. This study focuses on the implementation of AI technology into warehousing, especially in categorizing goods. After an overview of the recent literature on AI technologies and their application in the field of logistics, the introduction of an AI application follows. The main goal of the application is to categorize each good stored in a warehouse into ABC-XYZ groups, which determines the place of the good in the warehouse and the ordering frequency with the quantity. After acquiring and cleaning the training data from a real company, the determination and selection of the least input parameters is an important and challenging task, which is demonstrated. The effectiveness of the supervised learning can be seen as an ANN (artificial neural network) can output, with the aid of a non-conventional metaheuristic approach - the black hole algorithm - as the learning agent is demonstrated by an example, which also shows the result of an ABC-XYZ categorization run on a dataset from a multinational company.

1 Introduction and literature review

Recently, as we can see in the news, there has been a surge in the development and use of artificial intelligence (AI), not only in research and industry, but also active use in real life situations. So far, large corporations have used some forms of AI to determine the weather [1], to analyse compounds and tissues chemically and biologically [2], to trade stocks [3], to assess consumer needs [4], to create tailored advertising [5] or to run the largest text search systems [6], to name just the most well-known ones. Apart from the last decade, there has been mass-fear about the effect, power and awakening of artificial intelligence [7], which has been greatly influenced by the exaggerated media, but nowadays AI is mostly accepted as a useful tool that, if used properly, can do no harm. To give a concrete example, the open source chatbot ChatGPT is enjoying unprecedented popularity, with 13 million daily users and a total user base of 110 million in January 2023 [8]. It can engage in quasi-intelligent safe conversations, grant answers, and help on topics or write your homework, which has caused huge scandal in the US.

Considering this, it is hard to imagine that there are industrial areas where artificial intelligence is hardly used at all, neither in the design, nor in the construction, nor in the operational phases, although it is also mentioned in the Industry 4.0 principles and directions under the topic of automation [9,10].

Most researchers agree that automation and Industry 4.0 tools not only allow us to improve our hardware, but also to automate our software and decision-making systems [11]. To achieve this, existing enterprise databases, such as SQL-based ones, can be easily linked to program written in C#, .Net or MATLAB languages and

run AI supported queries on them continuously to find hidden parameter or process relationships [12]. This could easily lead to IoT-SL (Internet of Things - Smart Logistics) systems, where smart contracts and more effective services can increase warehouse efficiency, faster receipt actions, issuing, transferring, and picking [13]. One of the biggest and most advanced areas of artificial intelligence research is image processing, which is essential for self-driving vehicles and visual recognition systems. To train these systems, large amounts of data are needed, and if we want to continuously expand this data, we need to use cloud-based services. EDGE computing with AI-infused cloud services provides a solution for this problem [14].

In a warehouse, there are plenty of possibilities to use AI-driven or augmented systems. As I mentioned earlier visual recognition is in a very advanced state, which can be used to control safely fully autonomous vehicles [15]. Visual recognition and artificial intelligence have another big impact on warehousing within sorting and picking. Pick-by-vision owes its existence to smart glasses and the rise of augmented reality [16]. Although not yet widely adopted due to its relatively high installation cost and AI training time, but in the future, it could easily become more accessible [17]. As most of us know, pick-by-voice is a well-established technology, that can work without any major AI, but for better voice recognition or giving special instructions the method can be improved by AI [18].

Another unique example of the implementation of AI into warehouses comes from researcher Min-Chun Yu, with a great promise to compare the outcome of the original ABC analysis with methods infused by artificial intelligence [19]. The ABC analysis has a few variations, but most of them sorts the stored items in descending order by price multiplied by quantity of consumption, then using

the Pareto principle to classify them into categories A-B-C with 80-15-5% breakdown. A set of data provided as training and testing data for the three method of AI, which are: Back-Propagation Network (BPN), which is a type of Artificial Neural Network (ANN) and use a back-to-front normalising method for setting the weights of the node connections; Support Vector Machine (SVM), where minimal risk structures can be achieved by a linear model, and implementing vectors as margins of parameters; and k-nearest neighbours, which is a reliable clustering tool, that can be used for easy and fast grouping, but very sensitive for input and initial data. The study claims, that the SVM method worked the best, on average the model guesses the right categories with a success rate of nearly 80%. This study has inspired this research most. Recently real company data was received for optimization and research purposes, that could easily be used to create an ABC analysis dataset for AI testing and validating. The company also performs their own XYZ analysis on items, with which they can store more effectively and calculate shipping quantities better, thus improving their material flow and make a more efficient warehouse and logistic system.

This paper's purpose to create an example of training a weak AI, that can pre-categorize items based on a corporate supervised data set into both ABC and XYZ categories.

2 How artificial neural networks works?

Most of the time for categorizing tasks we don't need a very powerful or complicated AI models. Most logistic based problems are not a particularly complicated for this kind of tools: most of the time it doesn't need visual processing or text recognition with a human like response. In most cases there are a fixed number of parameters for inputs, and well-defined outputs. There are plenty of artificial models and techniques which we can use to solve this problem. One of the easiest, well described, and well-developed models are the Artificial Neural Networks (ANN). These are machine learning models, that are designed to simulate the way human brain works, where nonlinear classifiers mostly used to create and refine complex relationships between inputs and outputs for classification purposes. An ANN model contains several node-layers for processing information, called neurons. The layers are usually called input layer, hidden layer and output layer. ANN models can be used for a wide range of tasks, of which the best known for image and speech recognition or natural language processing. ANN models are trained on supervised data with the help of heuristics, or a process called backpropagation, where the algorithm adjusts the weights between neurons in response to the input data. This process iterates until the model is able to accurately predict the output for a given input in the test data. However, this process can also be computationally intensive and for complex problems, which is not always predictable, or require significant amounts of training data. After the learning phase the model can be used with a high

degree of certainty on actual data that has not yet been seen to give a proper output [20,21].

Backpropagation is a very powerful and tool for adjusting the weights of connections between nodes, but not the only one; we can also use heuristics for this purpose. The former is a simple and efficient techniques, that best at smaller standardized problems in matrix forms and fine-tuning already good solutions, but not so efficient in big complex and noisy datasets. It is also very sensitive for the initial settings and input parameters [22].

The heuristic approach is another good technique to adjust the weights, but it requires more computing power and the solution's correctness has a bit more uncertainty. It is good for any kind of problem, mostly without restriction, and with their application, it is possible to oversee a much larger spectrum of weight-solutions [23]. Most of the times when we search for heuristics in AI topics the genetic algorithm (GA) will dominate our findings. This method is a very good candidate for almost every problem including weight adjustments in ANN models, because it is very robust, easily calibrated, and have numerous versions included as packages in many programming languages and compilers. Genetic algorithm, however, is not the only good heuristic option. There are many cases, where other heuristics can surpass GA in different tasks, like in the paper "Black Hole Algorithm and Its Applications" [24]. The black hole algorithm (BHA) is a population-based metaheuristic algorithm with a semi-memory storage for solutions. Classification is the strength of this algorithm, which can work very effectively when the parameters are fractional numbers with limits, where we can interpret the "distance" between individual objectively [25]. In most ANN the numbers and their weights are predetermined and limited (-1...1), which is ideal for the BHA to work effectively. In addition to these, the basic algorithm of BHA is much simpler and works with much fewer steps than GA, so an iteration step is only a fraction of the time of GA. It also handles more populations more effectively because an iteration step doesn't require ranking or weighting the individuals, there are no special crossovers, only the best remains and the rest of the population changes. These are the reasons why BHA was chosen as the artificial neural network's weight calibrating tool, for the ABC-XYZ classification problem.

3 ANN model for ABC-XYZ prediction with black hole algorithm

To create a practical/industrial acceptable ANN model, two initial steps must be taken: data mining and layer (parameter) definition. The order of these is determined by whether we already have the data for testing that can be processed, or whether we are trying to create a new system and data collection will follow. In this specific case the access to corporate data was very useful, which is used as a test database after cleaning and pre-processing. Naturally, permission was granted by the company to use

their data in this research if the company and the goods cannot be recognized by competitors. This means the data collection came first and the definition of layers were the second step. There is only rule of thumb on how many hidden layers there must be (1 is always required): for not too complex tasks (with reasonable parameter count) most authors recommend between 1 and 3. The same applies to the number of neurons (or nodes) in the hidden layers: there are formulas, but since the number of parameters can be between a few and millions (image processing) it's very task dependent. For a small number (under 100) of input parameters the first hidden layer has a node count of

maximum twice the number of input and output parameters; the second hidden layer and after, the neuron counts should be between 2/3 and 1/2 of the previous layer [26].

After cleaning and processing the corporate data 9 inputs were selected, and of course 2 outputs: prediction of item classification into: ABC & XYZ. Because these are not high numbers, and from my understanding, this problem didn't look very complex, so I created 2 hidden layers with 12 and 6 nodes. These parameters and layers can be seen in Figure 1.

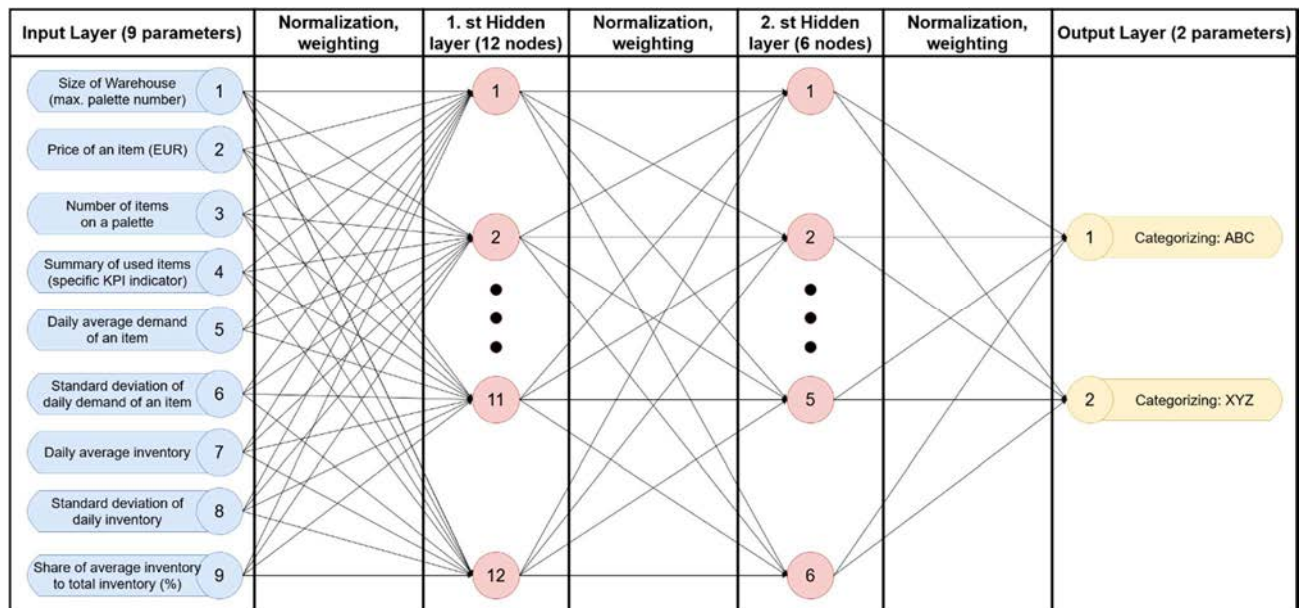


Figure 1 Layers of ANN network for ABC-XYZ prediction

3.1 Defining the input dataset for artificial neural network

Besides cleaning, pre-processing the data is almost always needed. If the whole cleaned dataset was given as input we had nearly 140 parameters (in daily breakdown), which is unnecessary. Input parameters 1...4 is not changed, these are the followings: size of warehouse (capacity by palette number of the location), price of an item in EUR, number of items in a palette, and a KPI indicator, which summarizes the number of used items (only left it in because it has been asked by the company). Input parameters 5...9 is calculated: daily average demand of an item, and its standard deviation, daily average inventory and its standard deviation, and the average of the daily percentage of an item occupancy in the given warehouse. With these inputs, we need to try to avoid having data that are part of other parameters or to express them by the relationships of other parameters. Always aim for the previous principle if effectiveness is the goal. The only exception is we have parameters that, although related, have a very complex relationship that can only be truly expressed through more layers that we have.

The corporate dataset contained information about nearly 3200 items, which was real storage and movement data for a whole month from multiple company warehouses broken down to the second. Unfortunately, about 1800 of the 3200 items were not active in the examined month, so more than half of the training data we lose by default. In addition, there were errors and gaps in the remaining dataset: there were some warehouses that doesn't classified items into ABC-XYZ, and most items had at least one parameter missing, like price or quantity. After the data cleaning only 255 items remained in the training dataset, which is still plenty enough to train an AI. Part of this cleaned and pre-processed data set is shown in Table 2.

In Table 1. we can see two yellow column ABC (Corp.) and XYZ (Corp.). These are the classifications defined by the company for every item in the testing dataset, and most importantly for AI developers, these are the supervised outputs, that we want to acquire at the end of the training process. Also, the green columns in the table are the input parameters and the grey columns (120 columns) contains the daily data, which used for the calculation of input parameters 5...9.

Table 1 Part of training dataset

Item no.	Warehouse size (palette)	Price of item (EUR)	Number of item on palette	Used palette number of item (KPI)	Daily average demand (palette)	SD of daily average demand (palette)	Daily average inventory (palette)	SD of daily average inventory (palette)	Average daily stock ratio	ABC (Corp.)	XYZ (Corp.)	Initial stock factory total (no. items)	Initial stock factory total (palette)	Income (no. item)	Used items (no. item)	Remains (no. item)	Stock (palette)
														03.25.2022	03.25.2022	03.25.2022	03.25.2022
N1	1155	258.46	24.00	6.83	23.43	9.22	58.43	15.34	0.0506	A	X	2208	92	0	552	1656	69
N2	1155	169.96	48.00	1.71	11.71	6.80	26.71	28.16	0.0231	A	Y	624	13	0	480	144	3
N3	1155	100.52	32.00	6.25	28.57	14.33	133.57	51.17	0.1156	A	Y	8224	257	0	1312	6912	216
N4	899	48.33	80.00	1.54	17.57	7.16	40.86	22.81	0.0454	A	X	2000	25	0	1760	240	3
N5	899	40.70	105.00	0.50	7.43	3.69	11.00	7.55	0.0122	A	X	945	9	945	945	945	9
N6	899	48.32	64.00	1.48	13.57	8.44	4.29	11.95	0.0048	A	Y	704	11	0	1344	-640	-10
N7	899	25.30	36.00	4.53	23.29	11.16	41.29	11.18	0.0459	A	X	2124	59	864	1116	1872	52
N8	1155	23.83	80.00	0.94	10.71	5.56	38.71	12.54	0.0335	A	Y	3680	46	0	1280	2400	30
N9	899	50.07	48.00	0.85	5.86	5.70	31.71	11.29	0.0353	A	Y	624	13	384	0	1008	21
N10	1155	25.89	48.00	1.69	11.57	5.44	42.43	22.71	0.0367	A	X	1152	24	0	480	672	14
N11	1155	137.22	48.00	0.23	1.57	2.07	3.86	3.02	0.0033	A	Y	288	6	0	0	288	6
N12	1155	21.50	50.00	0.72	5.14	9.25	74.29	24.74	0.0643	A	Y	1700	34	1700	1150	2250	45
...

3.2 The importance of ABC and XYZ analysis

The results of ABC and XYZ analysis are not the most important indicators or management parameters for the company, but they can be used as an easy decision support tool for the whole internal and external logistic system to manage the stock levels of incoming materials and items in the warehouses, plan stock entries and withdrawals, free up space, control delivery deadlines, prepare the right materials for product changes and plan the ordering quantities coming into and out of the factory with their time intervals.

ABC analysis aims to distinguish between items (mainly materials) that are significant and insignificant to the materials management system. It separates the essential from the non-essential based on the annual use (value and/or quantity) of the products, classifying them into 3 categories (A, B, C). The materials are grouped according to their relative importance and differentiated inventory management methods are applied according to the groups [27].

The pareto principle states: about 5-20% of the items cover 70-80% of sales these are "A" category items. "B" category items cover 20-30% of sales with 20-30% of sales and the remainder being "C" category. Pareto logic also states: the biggest savings can be achieved with "A" category because of its high value. This is certainly true because of the law of large numbers, but the other categories should not be forgotten, as "C" will be precisely those products that are sold infrequently and in small quantities. [27].

The results of XYZ analysis are to indicate and categorize the fluctuations in demand for items over a longer period. We can express market volatility in terms of the relative dispersion of demand. The "X" category includes those items whose consumption shows only minor fluctuations. This category is characterised by a high level of forecasting. The use of materials in category "Y" is more

volatile, but there is a certain tendency to fluctuate. For example, there may be a steady increase or a steady decrease, or perhaps seasonal patterns of use. This category is characterised by a medium forecast accuracy. Category "Z" includes materials whose use is completely irregular, with a very low forecast accuracy [28].

4 Application and results

There are many programming languages and compilers that can write ANNs effectively, but for research purposes, there is a very simple and effective programming language and its application that handles matrices very well, which is MATLAB. There was no doubt that the application was written in this language. Also programming in MATLAB was fairly easy with the pre-made libraries and the huge number of blogs on the internet was helpful in this topic. In addition, the implementation of the black hole algorithm, which is the core process of the model, was also relatively simple, because of its easy structure and comprehensibility. After a few unsuccessful runs, when the results did not improve, the solution was able to move forward with a simple trick: make the output neuron thresholds a variable. Previously, we had defined the values and the categories, when the first output neuron's value is between 0...0.33 was category "A", between 0.33...0.67 was category "B", and above 0.67 was category "C". This applied to the XYZ category also. After making the limits their own parameters, which can be modified by the BHA, the results improved significantly.

Figure 2 shows a complete run of the current best result of ABC-XYZ solutions. The run lasted around 9 hours on a currently very average computer (HexaCore AMD Ryzen 5 3600 CPU with 16GB DDR4 memory and NVIDIA GeForce GTX 1660 SUPER 6 GB video card). During this time, roughly 25000 iterations were performed with a population of 500.

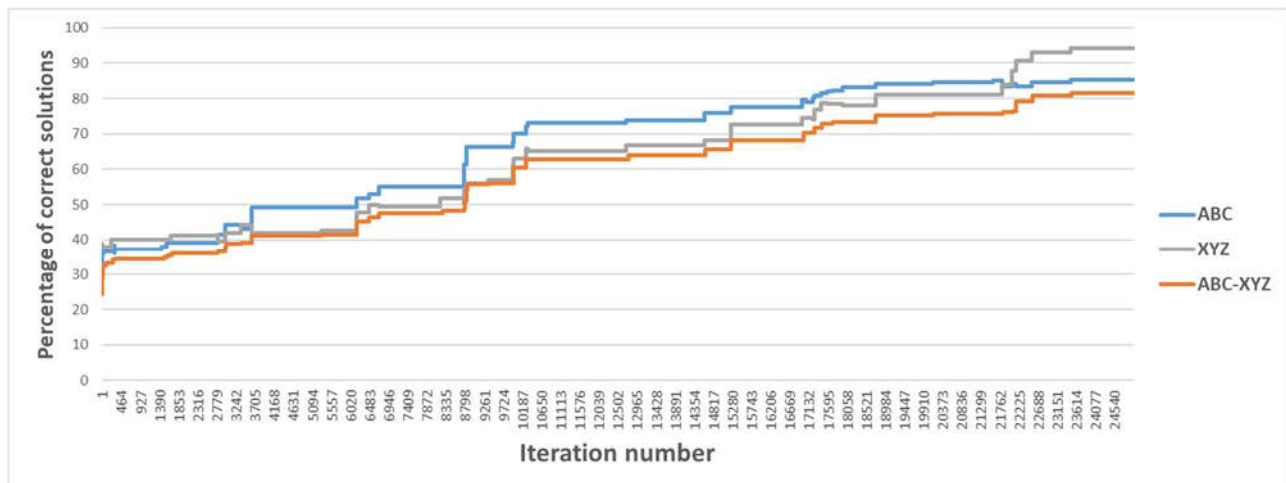


Figure 2 Result of an ANN performance for ABC-XYZ prediction

As Figure 2 shows the ABC-XYZ results starts at around 25% of good predictions of the 255 training data, which is statistically correct: there are around 40% of “C” category and 40% of “Z” category items. To predict only this category, which is the largest, there is a near 16% of correctness, just by categorizing every item into “C” and “Z”. After the initial categorization there is a quick improvement: in only 9000 iteration the model guesses the categories correctly 50% of the time. After the 25000 iterations, the model can categorize the training items into ABC category 85%, XYZ category 93% and both 82% correctly. This level is higher, than a normally skilled worker capable of, if he/she needs to categorize an item based only the item’s parameters, and without seeing the other item’s values. It is likely that if the application had more runtime, than the results could have gotten better results, and after a while it could have reached practically 100% accuracy, but given the slowing improvement, this task could have taken several days or even a week on this computer.

5 Conclusions

The usage of artificial intelligence in the field of internal logistics is rare, besides visual recognition in AGV and robotic systems, which can be also recognised from, the literature review. There are only a few literatures, which encourage the industry to implement high-level systems that support Industry 4.0 principles with AI-implementation, with which companies are much capable of making simpler decisions or assisting the logistics systems. These are both visual and background assistance benefits, mainly for easy transparency, flexibility, and easy management of materials and goods, and there are plenty of un-used databases that, can be a source for training data. The only literature, that can be found on the topic of this research is from Min-Chun Yu, who uses Artificial Intelligence to create a method for automatic categorization of warehouse goods into ABC. The ABC categorization is good for representing the quantities of

certain items in the system, but doesn’t show us the frequency of usage, which is also important to create a stable and optimal warehouse and manufacturing system. This research attempts to address this scientific gap in an unconventional way, by using an artificial neural network, to categorize each item of a given company into both ABC and XYZ categories, based on their own manual categorization. In most cases, such categorization manually will only give good results if you have had the item for a long time and have enough data about it. Another advantage of the AI-trained method is that the trained method does not need the data mentioned above. It can immediately categorize it with high accuracy, provided that the training was successful and appropriate parameters are available. A properly trained system can also handle faulty or incomplete items (parameters) to a certain extent, which increases the robustness of the system.

To prove the useability of the AI aided systems, an application was created in MATLAB, with the learning black hole optimization algorithm (substitute for the genetic algorithm and backpropagation, which are commonly used for this purpose), that the method can predict an item category correctly 82% of the time after an 8-hour running on an average computer. This can be improved by giving more runtime to the method or combine multiple algorithms to make it more efficient. In average this 82% is as good as an average human workers guess with some experience in the field of warehousing and logistics.

Future of this research: further testing of this model and an investigation on data from other companies, with these settings, to see the results and percentages of correctness. In addition, these questions should be answered in the future: Can we create a model and a set of rules consisting pre-determined weights, which will create good results with industrially accepted and collectable pre-defined inputs? Does the black hole algorithm aided AIs performed better, than a Genetic algorithm or backpropagation aided artificial neural networks?

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Cold warehousing services from the perspectives of logistics providers: the mediating role of cost and organizational readiness

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Keywords: intention to provide cold warehousing services, TOE framework, mediator, smart PLS 4, logistics service provider.

Abstract: Despite the importance of the cold supply chain in preventing food waste worldwide, there are only a limited number of cold chain providers in Malaysia. This study investigates the factors influencing the intention to provide cold warehousing service logistics providers in Malaysia. Employing a purposive sampling method, data were gathered via an online survey of logistics companies in Malaysia. 184 usable datasets were valid for further analysis. Owing to concerns regarding predictive purposes, structural equation modelling with SMART-PLS 4 was applied to test the hypotheses of this study. The analysis found all direct hypotheses were supported. The relationship between CEO innovativeness and intention, and government support toward intention, is positively mediated by organizational readiness. Meanwhile, cost failed to mediate the relationship between CEO innovativeness and intention. The study developed a new model with two mediators for a better understanding of the factors influencing the intention to provide cold warehousing services in Malaysia from the perspective of logistics providers. The findings will provide meaningful information for the government to craft a better policy to enhance the number of cold service providers.

1 Introduction

One-third of the 4 billion tonnes of food produced annually worldwide is wasted due to supply chain failures from farms to retailers and loss of final consumption in restaurants or at home. The number of food waste is estimated to grow annually. Food waste is a moral issue because almost 12 per cent of the population in the world is suffering from hunger. Lack of cold storage lead to food waste problems which are prone at developing nations. Temperature changes occurring in the cold chain lead to economic losses as well as lost market opportunities due to quality loss issues and export protocol deviations. Lack of cold storage is one of the major bottlenecks for an efficient and effective food cold chain. When capacity of cold storage is observed in secondary cities, it is often of poor quality, with variable or high temperatures, temperature indicators rather than digital, no shelving, possibly no pallets, lack of entrances, insulation, loading docks, and mechanization [1]. Therefore, cold warehouse is needed

not only to preserving cold products, but to ensure the products safety and quality before it arrived at the hand of end users.

Cold storage is vital to perishables and respective industries like Halal. According to [2], the cold storage market was valued at \$89.32 billion in 2018 and is projected to reach \$217.59 billion by 2026, growing at a compound annual growth rate of 11.71% from 2019 to 2026. The total capacity of refrigerated warehouses worldwide was 719 million cubic meters in 2020. Factors driving growth include online grocery sales, flat-rate meal services, consumer preference for fresh and perishable goods, and the rise of pharmaceuticals requiring special storage. Growth is seen at a compound annual growth rate of 11.71% from 2019 to 2026. A major challenge for the industry is that demand for cold storage is outstripping supply. In the United States (US), for example, the supply of refrigerated warehouses is outdated and the construction of modern facilities lags behind demand. Also, more than 78% of US cold storage were built before the year of 2000,

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suggesting that modern cold storage is often under-resourced. In Malaysia, the relatively high growth of refrigerated storage compared to refrigerated transportation can be attributed to the establishment of new facilities in free trade zones by industry players. This is because the investors prefer to invest in cold storage as it is a safer long-term investment despite the higher investment cost. Additionally, there is a seasonal spike in demand, especially during the fasting month of Ramadan.

Nowadays, cold warehouse is also needed to improve the value chain especially within developing country like Malaysia. Cold storage are fundamental aspects to prevent deterioration of the product quality. The demand for frozen foods such as frozen meat, ready meals, fruits, vegetables, cookies, fast foods, and bakery items is on the rise due to the rise of households, markets and retailers. This trend is also impacting the Malaysian logistics market. The cold chain market in Malaysia can be segmented into five major categories: fruits & vegetables, bakery & confectionery, dairy & frozen desserts, seafood, and pharmaceuticals. Due to the growing demand for perishable food, development of logistics hub and increasing demand for Halal products, the Malaysian cold chain market is anticipated to grow significantly. Halal cold chain products require sea/airport complex while [3] stated that an appropriate logistics infrastructure such as cold warehouse and other cold chain facilities also needed for managing halal supply chain in Malaysia. Malaysia has established itself as a hub for the halal industry, driving demand for cold storage. However, [4] stated that the adoption of cold chain is low among developing country. Moreover, [5] stated that only few cold chain providers exist in Malaysia makes this industry is a niche area and it can be seen from the small number of registered cold chain operators in the Malaysia Logistics Directories. Nonetheless, logistics providers in Malaysia remain uninterested to provide cold warehousing services despite the high demand and potential. Therefore, the study would discover factors influencing the intention to provide cold supply chain services among logistics providers in Malaysia.

Various previous study was discussing cold chain in the context of food safety, temperature break and condition, last mile delivery [6], supplier selection [7], monitoring application [8], and service innovation, however not many studies conducted to investigate the service innovation from the perspective of service providers. The purpose of this study was to expand the cold chain literature by understanding the considerations of cold storage providers before offering relevant services in developing countries, including Malaysia. As a result, this study could be reference by service providers within developing countries prior to their consideration for becoming one of the cold warehouse service providers. By applying a quantitative approach based on the TOE framework, the current study sought to fill gaps in the existing literature by identifying factors that contribute to Malaysian logistics providers' intention to provide cold warehouse services. Moreover,

despite the importance of CEO innovativeness and cost, this relationship was not thoroughly tested in the supply chain studies especially for the adoption cold warehousing services. On top of that, even government support is fundamental to encourage organization adoption of new technology or new approach, lack of study looking at this variable with the organization readiness. While there is no agreed-upon accepted conceptual framework and/or reference model for use by academics and practitioners working in the industry of cold chain, conceptual/reference models abound in other fields, but cold supply chains have not received similar attention [9]. The cold chain is thus fertile ground for further work. Nevertheless, cold chain LSP in emerging market is an appropriate context for generating new insights on the service innovation research. This makes the service innovation like cold warehousing adoption within developing countries is still promising topic in research.

The study contributes in numerous ways. First enriching literature in cold warehousing services adoption from the perspectives of service providers. Second, the study introduces the relationship between CEO innovativeness and cost. Third, exploring the relationship between government support and the organizational readiness, which is very limited in the adoption literature, and scarce of studies were look at the relationship between them. Fourth, lack of mediation analysis in the TOE framework, but, the studies introduced two mediators which is cost and organization readiness. The findings of the study could be applied to various countries who has similar characteristics with Malaysia.

2 Literature review

This section discusses related literature, develops hypotheses, and elucidates the research framework.

2.1 Cold warehouse

Perishable products are prone to degradation as soon as they're harvested. Therefore, a proper post-harvest handling are essentials for maintaining the quality and prolonging its shelf life. Thus, cold storage is needed to fill the role. In cold warehousing, the most important design elements are low temperature, temperature uniformity across the room's cold compartment, temperature stability with minimal fluctuations, good air distribution to maintain temperature uniformity, minimal temperature to avoid dehydration, air circulation, and minimal air inflow to minimize fluctuations.

2.2 The technology-organisation-environment (TOE) framework

The TOE Framework describes how organizational context influences the adoption and implementation of innovations in three different ways [10]. The TOE framework explains that three different elements of a firm's context influence adoption decisions comprises

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technological context, organizational context and environmental context. The technological context includes all technologies that is relevant to the firm either already in used or are still available in the market. The Organizational context refers to company characteristics and resources. While environment context embraces the structure of the industry. In this study, cost is representing the technological context, CEO innovativeness and organizational readiness representing organizational context, while environmental context is represented by government support. Because the TOE framework incorporates both human and non-human factors into one framework, TOE provides a more comprehensive view of technology adoption.

2.2.1 Cost

Cost can be referred to the expenses that a firm incurs to sustain cold warehousing which has a significant influence on executive's decision making [11]. The high initial cost to adopt cold warehousing includes the refrigeration system, acquiring new building or upgrading the existing building that suitable for cold storage, systems monitoring for temperature control, and backup power systems to prevent power outage. Nevertheless, the running cost of cold warehousing also very high due to the high energy consumption for the refrigeration system and also the indirect cost such as hiring new employees or training existing staffs. High installation and operation cost preventing efficient cold supply chain in developing country. High electricity bills have been repeatedly pointed out as a problem for cold storage and electricity costs are higher in the remote regions than in the capital [1]. This is why [12] confirmed that cost is the only variable that significantly act as barrier to Halal warehouse adoption. Previous studies confirmed that cost has negative effect toward the intention to adopt new technology. Thus, the study proposed that:

H1: Cost negatively influence the intention to provide cold warehousing services.

2.2.2 Organization readiness

Organizational readiness can be defined as the accessibility of organizational resources required for deployment of cold warehouse [13] in term of financial, manpower and technology resources. Organizational readiness could be limited by technology and financial resources. Prior for cold warehouse adoption, company definitely need to have expertise and essential knowledge to properly manage the adoption. Preparation in financial, human resources and technology may determine the level of organization readiness towards the cold warehouse adoption. Previous study by [14] confirmed that OR has positive effect on intention to adopt supply chain analytics system. Postulated to that, the study proposed:

H2: Organizational readiness positively influence the intention to provide cold warehousing services.

2.2.3 CEO Innovativeness

CEO is an entrepreneur figure who is crucial in determining the innovative attitude of a firm which openness to follow new ways and methods [15]. CEO's innovativeness is the extent to which a CEO is willing to actively adopt new management techniques and technologies to improve the organization. CEO are supposed to have power in influencing the firms' strategies and related performance. Thus, CEO can alter the direction of a company either to object or support such decision on technology adoption consequently allocating necessary resources. CEO are the key decision makers whose decision can influencing current and future activities of firms'. This is because CEO can drive their firm to adopt strategies that deviates from industry norms in order to become more innovative by communicating and implementing compelling visions. [16] mention that CEO innovativeness has a positive association with innovation adopted over last few years, this is because they are not only risk-takers, receptive towards new technology and view thing differently, they are also consistence and visible in committing funds and resources for new technology.

Innovative CEO can alter the effect of cost barrier towards cold chain adoption. The CEO can overturn the cost barriers by finding financial solution to support the cold chain adoption. This is aligned with [15] where innovator CEO would prefer solutions that change the structure in which the problem is embedded. Therefore, innovative CEO would have a negative influence towards cost barriers in providing cold warehousing services. Those innovative CEO surely can give effect towards organizational readiness by giving instruction either to allocate necessary resources prior to cold warehouse adoption. Since CEO is the ultimate decision maker in a firm, this makes the CEO can direct the firm readiness to adopt cold warehouse. Thus, the study proposed that:

H3: CEO innovativeness negatively influence cost of providing cold warehousing services.

H4: CEO innovativeness positively influence organizational readiness.

2.2.4 Government support

Government support refers to the extent to which a company is affected by government activity that stimulates the cold chain industry by creating basis and values needed for adoption [17]. Support from the government can be represented as the nationalized legislation, tax refund compliance, industrial standards, hardware infrastructure, or even media publication. Support from government could provide favourable environment thus removing barriers to adopt cold warehouse. Governments can encourage companies for innovation adoption, by supporting firms through the appropriate imposition of tax laws and

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beneficial firm development policies. When support is ample, most probably the cold warehouse adoption tends to be quick. Because of the ease in legislative and financial incentives, the burden of an organization can be reduced and increasing the readiness towards cold warehouse adoption. Thus, the study proposed that:

H5: Government Support positively influence organizational readiness.

2.2.5 Mediator (Cost and OR)

Mediation commonly used as contributions for studies in social science. In an emerging market, costs for cold chain adoption is higher and riskier due to the inadequate infrastructure and chronic shortage of resources. More investment on equipment, human resources and IT facilities, bears higher operations costs and are more vulnerable to institutional environment, for the involvement in cold chain logistics services, [18] stated that cold chain industries are facing numerous challenges including high cost where it accounts for 30% of the global energy consumption. It was believed that cost could mediate the relationship between CEO innovativeness toward the cold warehouse adoption. Innovative CEO tend to favours for technology adoption. However, due to the high initial and running cost of cold warehousing, the is a likelihood that CEO will turn down the adoption. The financial cost could be negative determinant for company affordability to adopt cold warehouse. However, the characteristics of innovative CEO can alter the willingness of such company to adopt technologies for improving the organization.

Besides, this study is proposing that the organizational readiness could be mediated by CEO innovativeness and government support. This means that the openness of CEO to adapt new technology and the encouragement by the

government in the form of legislation and financial stimulation could influence the readiness of an organization to adopt cold warehouse. The CEO generally has full control over organization’s financial and human resources which could be used to support for information gathering regarding their competitors as well as to allocating requisite financial resources for cold warehouse investment. Based on [15], technology adoption consideration by the CEO happens when company has achieved organizational readiness for its financial and organizational resources in order to maintain or gain their competitive edge.

According to, the government support as administrative and financial incentive promoting the introducing of new technology to the company. This support allowing soon to be cold warehouse providers to prepare their readiness towards financial and human resources. Government holds a significant role in determining the regulations through facilities and governing work pattern which impacting the company readiness to adopt cold warehouse. Thus, government can use their tools and policies to ease the financial and human resources aspect in serving readiness of cold warehouse adopters. Figure 1 illustrates the research framework of the study.

Postulated to that, the study proposed:

H6: Cost negatively mediates the relationship between CEO innovativeness and intention to provide cold warehousing services.

H7: Organizational readiness positively mediates the relationship between CEO innovativeness and intention to provide cold warehousing services.

H8: Organizational readiness positively mediates the relationship between government support and intention to provide cold warehousing services.

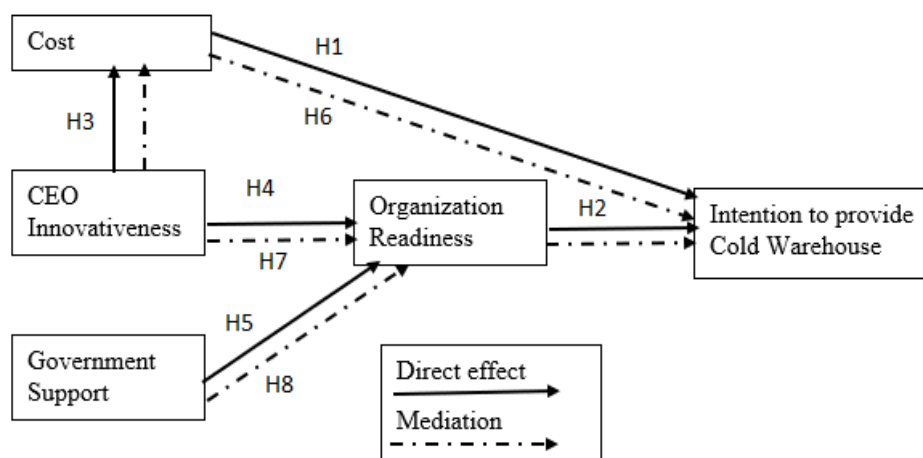


Figure 1 Research framework

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3 Methodology

Due to unit of analysis of the study is at the organization, thus, only managers from logistics providers who not yet providing cold warehousing services are valid respondents of the study. To ensure respondents' validity, a filter question "My company offer cold warehousing services" was added in the beginning of the questionnaire.

3.1 Research instruments

The measurements of the study were adopted from established literature in supply chain studies. CEO innovativeness was adopted from [19] cost. Organization readiness and intention from [12] and government support from [20]. To address the common method bias using the procedural method, the study employed different anchor scale [21] to measure the endogenous variables (1-5) and exogenous variable (1-7).

3.2 Sampling method and data collection

Since the population of the study in unknown, the study employed the non-probability sampling method . Since the study focus on the non-provider of cold warehousing services, thus the study will rely on the purposive sampling method. Based on the list of logistics provider acquired from the Malaysia Logistics Directory, the study contacted all the companies to ensure their willingness to respond to the study. Among 645 companies, 420 were agreed to respond, thus, the study proceed the questionnaire via email. Out of 420 emails, only 195 were responded completely. After through scanning, only 184 were valid respondent for the study.

Since the study focus on the predictive purpose, Smart Partial Least Squares (PLS) 4 [22] was applied using a structural equation modelling (SEM) approach. As proposed by [23], while using the Smart PLS software, the must ensure that the sample size is sufficient to test the research model. Employing the G*Power, with 80% power, medium effect size and $p = 0.05$, proposed by [24] with two predictors in the research model, the minimum sample size is 68. Thus, with 184 sample of the study, it is confirmed that sample size was not an issue for the study.

Out of 184 respondents of the study, majority of the respondents were assistant managers (52.7%). Moreover, 60.3% of them is having less than 5 years of experience in the current job positions, 56% of the respondents were Diploma holders, 60.3% of the respondents were male. 56% or most of the logistics providers involve in the study are from large size, and interestingly, 73.4% of them are local companies. Most corporations (74.5%) were established above 9 years. More than half (51.6%) of the companies focused on handling food products.

4 Analysis

4.1 Common method bias

Since the data were collected from a single source, it might lead to common method bias. The study used procedural method by applying different anchor scales to measure exogenous and endogenous variables [21]. For statistical method, following [25] the study used a full-collinearity testing to remedy the CMB. Table 1 illustrates the results which shows that all the VIF values were lower than 3.3 [25], thus suggesting the CMB was not severe for the study.

Table 1 Full collinearity

Construct	CEO	COSTS	HR	ITTN	GS
VIF	1.994	1.332	2.524	2.088	1.535

4.2 Measurement model

The established the measurement model, two types of validities must be established; convergent validity and discriminant validity. The convergent validity will be established if the loading and average variance extracted (AVE) is ≥ 0.5 and the composite reliability (CR) is ≥ 0.7 . [26]. The analysis shows that all the loading, AVE and CR were higher than acceptable threshold value, confirming that the convergent validity has been established for the study. Table 2, illustrates the value for loading, AVE and CR of the study. On top of that, using the hetro-trait monotrait ratio, all the values were lower than 0.85 as suggested by [27], thus confirming the study also having no problem to establish the discriminant validity.

Table 2 Convergent validity

Construct	Item	Loading	CR	AVE
CEO Innovatiness	CEO1	0.868	0.944	0.808
	CEO2	0.912		
	CEO3	0.885		
	CEO4	0.930		
Cost	COSTS1	0.807	0.846	0.583
	COSTS2	0.811		
	COSTS3	0.827		
	COSTS4	0.583		
Intention	ITTN1	0.987	0.993	0.979
	ITTN3	0.990		
	ITTN5	0.991		
Government	GS1	0.923	0.951	0.866

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Support	GS2	0.934		
	GS3	0.936		
Organizational Readiness	OR1	0.862	0.871	0.771
	OR2	0.809		
	OR3	0.895	0.943	0.893
	OR4	0.927		

Table 3 Discriminant validity (HTMT)

Construct	CEO	COSTS	GS	ITTN	OR
CEO					
COSTS	0.530				
GS	0.455	0.415			
ITTN	0.627	0.378	0.457		
OR	0.679	0.434	0.629	0.728	

4.3 Structural model

To test the hypotheses, develop from the research framework, the study carried out the bootstrapping with 5000 iterations to calculate path co-efficient. The hypotheses will be claim as supported if the beta value is similar with the direction of hypothesis, T-value ≥ 1.645 , P value ≤ 0.05 and there is no zero value between the lower level (LL) and upper level (UL) of the confidence interval [23]. Prior to that, the multi-collinearity among the construct must be assessed. The study will be freed from collinearity if the variance inflated factor (VIF) were lower than 3. 3. Table 4 shows that all the VIF values were lower than 3.3, confirming that collinearity was not a threat in the dataset.

All the direct hypotheses of the study were supported. For the H1, the findings suggested that COST→ITTN ($\beta = -0.118$, $P < 0.05$) thus, confirming the negative effect of cost on ITTN, and supporting the H1 of the study. The study proposed OR to has a positive relationship with ITTN for the H2. With ($\beta = 0.641$, $P < 0.001$), thus confirming that OR positively influence ITTN, thus supporting the H2 of the study. For the relationship between CEO→ COSTS ($\beta = -0.477$, $P < 0.001$), the analysis shows that the CEO innovativeness negatively influence cost, thus supporting the H3. For another direct analysis related to the CEO innovativeness, the study hypothesized that CEO positively affect the OR. The analysis shows the evidence of the positive relationship between CEO→OR ($\beta = 0.460$, $P < 0.001$), thus supporting the H4. As the last hypothesis for the direct effect, the GS

was hypothesized to has a positive relationship with OR. With ($\beta = 0.382$, $P < 0.001$), it is confirmed that GS has a positive relationship with OR, hence H5 was supported.

From the research model, there are three endogenous variables for the study. 22.8% variance for cost was explained by CEO, 48.1% variance for OR was explained by CEO and GS, meanwhile 50.6% variance of ITTN was explained by OR and COST. As the hypotheses were supported, it is crucial for the study to report the effect size (f^2). Effect size was categorized by [28] with small (0.02), medium (0.15) and large (0.35). H1 and H3 have a medium effect size, meanwhile H2 and H4 were having a large effect size, meanwhile H5 only managed to has a small effect size. Table 4 illustrates the analysis for the direct hypotheses of the study.

To enhance the predictive power, the study suggested COST and OR as mediators within the framework. Using the [29], to bootstrapping the indirect effect, and the analysis found that cost was not having a mediation effect for the relationship between CEO and ITTN ($\beta = 0.056$, $P = 0.051$, LL -0.001, UL 0.112), thus H6, the first hypothesis for mediation was unsupported. As expected, OR was found to positively mediates the relationship between GS and ITTN ($\beta = 0.245$, $P < 0.001$; LL=0.166, UL = 0.332), thus supporting the H7. Lastly, OR also was found the positively mediated the relationship between CEO and ITTN ($\beta = 0.295$, $P < 0.001$, LL = 0.202, UL = 0.390), thus supporting the H8. Table 4 and figure 2 illustrates the summary of findings for the hypothesis testing.

Table 4 Hypotheses testing result

Hypothesis	Relationship	Beta	SE	T Value	P value	LL	UL	VIF	F2
H1	COST→ ITTN	-0.118	0.072	1.645	0.050	-0.236	-0.001	1.159	0.023
H2	OR → ITTN	0.641	0.060	10.757	0.001	0.532	0.732	1.159	0.684
H3	CEO→COST	-0.477	0.061	7.775	0.001	-0.584	-0.379	1.000	0.295
H4	CEO → OR	0.460	0.076	6.036	0.001	0.330	0.579	1.215	0.353
H5	GS → OR	0.382	0.066	5.758	0.001	0.278	0.495	1.215	0.243
H6	CEO → COSTS → ITTN	0.056	0.034	1.643	0.051	-0.001	0.112		-
H7	CEO → OR → ITTN	0.295	0.058	5.071	0.001	0.202	0.390		0.087
H8	GS → OR → ITTN	0.245	0.051	4.841	0.001	0.166	0.332		0.060

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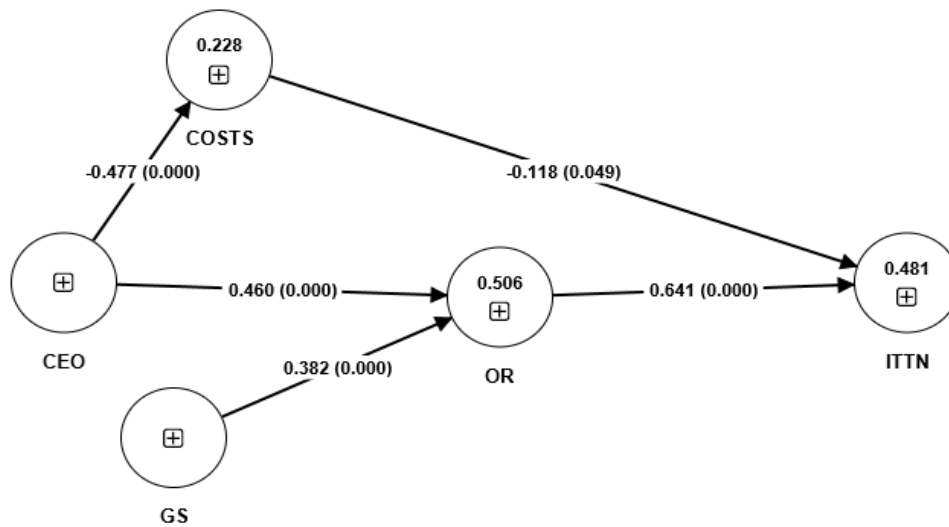


Figure 2 Structural model

4.4 PLS Predict

As the study concern on predictive purpose, PLS predict analysis was performed to measure the predictive relevance. Firstly, the value of Q² must be > 0, before looking at the Root Mean Square Error (RMSE) from PLS modelling and Linear Modelling (LM). The analysis will indicate the errors for each modelling techniques. Thus, if the value from PLS RMSE were lower than LM RMSE, indicating lower error, thus producing higher predictive power. As proposed by [30], if the result from PLS RMSE

- LM RMSE shows all negative values, the model has strong predictive power; if majority was negative, moderate predictive power, if minority was negative, low predictive power, while all positive value indicating of the prediction was not confirm. Table 5 shows that for Cost an OR, majority of the items produce negative values, indicating for both variables have a medium predictive power. Meanwhile for ITTN, since the result shows all negative value, suggesting the model for ITTN has a strong predictive power.

Table 5 PLS predict

Item	Q ² predict	PLS-RMSE	LM RMSE	PLS-LM	Decision
COSTS1	0.132	0.802	0.804	-0.002	Medium
COSTS2	0.083	0.729	0.752	-0.023	
COSTS3	0.212	0.874	0.895	-0.021	
COSTS4	0.015	1.007	0.96	0.047	
ITTN1	0.361	1.572	1.598	-0.026	Strong
ITTN3	0.348	1.526	1.537	-0.011	
ITTN5	0.37	1.522	1.529	-0.007	
OR1	0.45	0.786	0.791	-0.005	Medium
OR2	0.251	0.872	0.881	-0.009	
OR3	0.397	0.824	0.8	0.024	

5 Discussion

The study aims to unearth factors influencing the decision to provide cold warehousing services among the logistics providers in Malaysia. To achieve the research objectives, the study employed the TOE framework, by providing five direct hypotheses, and three mediations as contribution for the study. Besides enriching the limited literature in cold supply studies, especially in warehousing services from the perspectives of logistics providers, the findings of the study also provides meaning information for many parties involves in the industry.

For the first hypothesis, the study found that cost is negatively influence the intention to provide cold

warehousing services. Higher cost to provide will lower the intention to become cold warehouse service provider. The finding supported [12] in their adoption of Halal warehouse studies. Since cost is a crucial factor faced by the current logistics providers, thus they should come out with creative and meaningful solution, since cold warehousing services has a bright future and lower competition in Malaysia [3]

Organizational readiness was found to have a positive effect on the intention to provide cold warehousing services. The study portrays that higher readiness will increase to intention to provide cold warehousing services. The finding is supported by [14] who found that organizational readiness positively influences the adoption decision. The finding signalling that, while the

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organization is ready in term of human resource and financial, they also will have a higher intention to become a provider for cold warehousing services. Thus, parties who could boost the organization readiness such as higher institution to provide qualified human capital, and financial institution to back up the arrangement to become cold warehousing services in near future since increasing their numbers will be helpful to many parties including themselves.

CEO innovativeness also has a favourable relationship with cost of adoption. Higher CEO innovativeness will lower their cost, thus supporting the negative relationship between them. The finding is similar with [15] who claimed that innovative CEO will provide a good solution to solve the firm limitation. Thus, hiring an innovative CEO not only good for the company's image, but also will reduce the operation cost for the organization.

CEO innovativeness also found to have a positive relationship with organizational readiness. The finding was supported by previous study by [16] who found that CEO innovativeness positively affect organization future behaviour. This finding indicates that high CEO innovativeness will produce higher intention to adopt new technology in their business activities. Hence, appointing innovative CEO not only will lowering the cost, but also escalation their organization intention to adopt new way of conducting business, such as providing new diversification from current business from conventional logistics provider, to become a cold warehousing provider.

Another supported hypothesis with the organizational readiness is government support. The findings supporting the idea of [31] who suggested that the government should provide favourable environment which will eliminating barriers to provide cold warehousing services. The study agreed with [32], government support could be implemented by imposition of tax laws and many other financial assistants to encourage companies to improve their services for the sake of the gross domestic products and also delighting the community's requirements.

For mediation analysis, the study found cost did not mediate the relationship between CEO innovativeness and intention to provide cold warehousing services. It shows that, if the logistics providers truly believed benefits will outweigh the cost, whatever cost, they are willing to bear for the sake of future benefits. Even the demand for the cold warehousing services in increasing, and lack of competitors in the business, however, the cost needed to penetrate the market is too big for them, thus justify why the cost did not mediate the relationship between CEO innovativeness and intention to provide cold warehousing services.

Organization readiness positively mediates the relationship between CEO innovativeness and government support toward intention to provide cold warehousing services. Thus, indicating the important of organizational readiness in supporting the decision to provide cold warehousing services among logistics providers in

Malaysia. The findings strengthen the idea of the importance of organizational readiness prior to organization to explore new business in their organization. Thus, if they are willing to offer cold warehousing services, by all means, the human resource and financially must be wealthy enough since it requires a lot of works and money to be part of the cold warehousing providers.

5.1 Theoretical contribution

Present study has successfully enriching literature in TOE models in the perspective of cold warehousing service provider. The exploration of empirical confirmation of mediation analysis for CEO innovativeness and GS by OR has managed to contributes in the TOE model. This result can be replicates and further develop in other settings. Despite the unsuccessful of establishing mediation analysis between CEO innovativeness and cost towards intention, this means that there's still an opportunity for other research to be conduct to confirming this theory further. The non-confirmation maybe due to the unsuitable context or setting to test the idea.

5.2 Practical contribution

Discoveries in this study has predominant connotation for the development of cold warehouse industries especially within the developing countries. The practice of cold warehouse to upsurge the value chain benefiting every level within the channel echelon and perquisite the consumers. Enhancement in cold warehousing were expected to be and answer for the global foods waste morale issues. The results are useful for every stakeholder to consider their stands for promoting cold warehouse adoption. This could also be tools for managerial consideration to gain market share in this industry.

This model shows that CEO and the government play vital roles against the readiness of warehouse providers. CEO through their innovativeness must able to remedy any barriers in the form of financial and human resources. Whilst the government on the other hand must provide as much aids as possible in the form of tax reliefs and reducing unnecessary legislation [3]. By doing this, the promotion of cold warehouse supposes to succeed.

6 Conclusion

Results in this study has ascertain the key factors influencing the intention to adopt cold warehouse services which useful to improve the value chain towards consumers. Specifically, all five direct hypotheses were supported, whereas only one of the three proposed mediation hypotheses was unsupported. CEO innovativeness, GS and OR remains the contributors to cold warehouse adoption subsequently enriching the literature in both TOE model and also in cold warehousing. The investigation has proved that CEO innovativeness and GS can be mediated by OR towards the intention of service providers for considering to offer cold warehouse.

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Knowledge in this study may become basis for CEO and government to find ways in promoting cold warehouse. CEO and government could steer the direction of company and industries through finding creative solution and preparing company to cold warehouse adoption. Nevertheless, the mediation roles of cost were insignificant to change the view of CEO towards cold warehouse adoption. Despite the innovativeness of the CEO towards beneficial of cold warehousing, cost remains preventer towards any technology adoption. Thus, the decision to provide cold warehousing services is not solely dependent on organisational readiness or CEO innovativeness but also on technology and environmental factors in motivating logistics providers to offer cold warehousing services. Other parties, especially the government, should also assist in increasing the number of cold chain providers in Malaysia, which will not only benefit the logistics providers but also improve the quality of foods for citizens while reducing the waste amount in the country.

6.1 Limitation and recommendation

This study has several limitations which can endorse for further research. Only four variables were tested namely cost, CEO innovativeness, government support and organizational readiness in the model. It is suggested that more variables should be included in the framework for future development in this area. As for now, there's only two mediation variables were used which is cost and OR. Therefore, more mediation analysis should be included for further explaining the phenomenon of deficiency within cold warehousing.

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Cold warehousing services from the perspectives of logistics providers: the mediating role of cost and organizational readiness

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Employee engagement in logistics industry: a perspective in Indonesia

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Keywords: logistic industry, leadership style, employee engagement, corporate reputation, internal control and corporate governance.

Abstract: Indonesia has a lower employee engagement rate than other nations in Southeast Asia, and this phenomenon applies to all industries, including the logistics sector. The logistics industry generally contributes a critical portion of a nation's economy, so further study of the management effectiveness in logistics companies is essential. Any company requires a reliable workforce to function at its best. This research investigates some variables influencing employee engagement in the Indonesian logistics industry. The first variable is corporate governance; the second variable is internal control; corporate reputation is the third, where all these three are set as independent variables. The research also examines whether leadership style moderates the influences of the three independent variables on employee engagement. This study collected data research by distributing questionnaires to 742 respondents from 353 logistics firms. Statistical results came from the Partial Least Square-Structural Equation Modelling (PLS-SEM) method used in this study. The findings revealed that the three independent variables positively and significantly impacted employee engagement. The leadership style functioned as the moderating role in corporate governance's impact and the corporate reputation's effect proven in this research; in contrast, it did not apply to internal control's impact. These results suggest that logistics companies in Indonesia can improve employee engagement by ensuring exemplary implementation of the three independent variables while adopting a leadership style that supports these efforts.

1 Introduction

An important field of any national economic growth contributor is the logistics industry. According to [1], Indonesia's logistics industries contributed 21.3% of the Gross Domestic Product (GDP) 2021. It indicates that this sector significantly contributes to the country's economy, and its survival is critical. In 2018, Indonesia's logistics performance index was ranked 46th globally by The World Bank [2], categorizing it as one of the lowest regions. It indicates that this sector has substantial room for future growth, which must come from the government and private organizations. Companies must use their resources optimally to achieve corporate goals due to the increasing business competition [3]. This fact is also in addition to the need for change from conventional to digital-based companies with employee support. The pandemic also accelerated the necessity of transforming into a digital world, forcing all sectors to switch to digital-based operations immediately.

The quality of human resources can be measured through employee engagement (EE), which shows how much they are psychologically and physically available

[4]. High employee loyalty improves performance within the corporate space. This finding proves that a solid employee is required to strengthen the organization's competitiveness [5]. The new trend that emphasizes the necessity for employee engagement study is the frequent change of jobs by the millennial generation due to their lack of loyalty and concern about the work atmosphere rather than building a career and getting promoted while staying in the same workplace [6]. Secondly, most companies with open job vacancies need applicants with various work experience, and they expect newly recruited employees to adapt quickly to the environment without basic training [7]. Based on empirical evidence, most innovative companies with better customer service have higher stock performance and fewer employee resignations than their competitors [8]. Most leaders usually focus on the corporation's positive impact of high employee engagement because it significantly contributes to organizations, given its substantial role and numerous advantages. Gallup [9] stated that companies having more solid employee engagement grades outperform firms with low engagement rates in absenteeism, well-being, safety

incidents, patient safety, quality, depreciation, profitability, productivity, output, sense of belonging to the establishment, and customer loyalty or engagement.

When it comes to employee engagement, top management must also understand the critical factors for the success of its company. Corporate governance (CG) fosters a positive working environment that increases employees' effectiveness and efficiency. According to Saratun [10], modifying organizational culture will encourage the employees' growth while maintaining high trust and justice. Good corporate governance and internal control (IC) create an excellent working environment and boost the employees' comfort, which can keep their psychological health while working in the company, thus creating a more substantial possibility of engagement. An exceptional corporate reputation (CR) leads to significant engagement because employee seeks not only physical wealth, such as money but also psychological wealth, such as their reputation, when working in a reputable company, thus can become why they get more engaged. In the logistics industry, the three variables mentioned play a critical role in daily operations. They are not solely based on past research but are an integral part of actual business processes. Therefore, considering them as research variables is a logical option.

Therefore, these establishments must implement top-notch corporate governance to achieve solid employee engagement. Strict internal control promotes attaining business goals and reduces uncertainty, which employees generally dislike. Mutnuru [11] reported that applying internal control in small entities' workplaces directly connects to employee engagement. Meijman and Mulder [12] further stated that effective IC implementation contributes to a positive work environment. A company's reputation is crucial because employees must feel secure in their working environment. The business's reputation influences its confidence in attaining sustainability, comfort, and other related factors. Ali and Ali [13] reported that it significantly impacts employee engagement. Similarly, Shirin and Kleyn [14] stated that this variable is an essential determinant of employee engagement. Even in volatile working situations, corporate reputation minimizes employee tiredness and desire to leave [15].

This research investigates whether exemplary corporate governance implementation improves employee engagement. The research investigates whether strict internal control practice enhances employee engagement and whether corporate reputation value has the same impact. The study also further assesses whether leadership style (LS) improves the effects of the three independent variables on employee engagement in the Indonesian logistics industry. There is limited past research that studies the impacts of the three independent variables on employee engagement; notably, there are no past researches that examine the impact of leadership style as the moderating variable between these independent variables and employee engagement. Indonesia is known

for its diverse culture; thus, leadership became one of the most critical variables because diverse cultures mean various leadership styles that can be implemented, thus becoming this study's originality. Therefore, the findings of the research can enrich body knowledge about employee engagement in logistics industry, especially in Indonesia context.

2 Literature review

2.1 Corporate governance

Indonesia has a national committee that oversees the implementation of good corporate governance pillars, including related policies, called *Komite Nasional Kebijakan Governansi* (KNKG). This committee helps to encourage healthy economic growth and create a conducive business climate [16]. KNKG strongly encourages companies operating in the country to adhere to five fundamental business pillars, called TARIF. The TARIF stands for transparency, accountability, responsibility, independence, and fairness, generally standard rules or principles in good corporate governance.

2.2 Internal control

Internal control is a set of procedures to ensure accurate and reliable business performance in compliance with prevailing rules and regulations [17]. The senior management team implements the procedures using various tools and techniques to achieve the objectives related to reporting and compliance. Smaller organizations will likely experience financial issues [18]. The quality of corporate internal control is determined based on how a company's different units or departments are organized, its owners, the audit process, and other factors. These include the board characteristics, committees, ownership structure, internal audit quality, and regulatory and market environments [19]. Vijayakumar and Nagaraja [20] stated that sound internal control is essential in a corporation because it mitigates the possibility of risk. This variable also ensures that employees adhere to company policies and ascertains it is smoothly run [21].

2.3 Corporate reputation

Corporate reputation is the image portrayed based on the activities carried out by the organization. Martineau [22] stated that a product's appearance combines functional and psychological characteristics. This statement aligns with the finding from Scott Cutlip that images are pieces of information containing essential attributes, such as beliefs, ideas, or impressions [23]. Corporate reputation portrays an organization as critical personnel, such as employees, customers, etc. Specific actions like procrastination can damage it and take many years to rebuild. Corporate reputation is an evaluation of stakeholders by their direct experiences with the organizations, including the use of all communication

channels that provide information on their actions and activities, according to Gotsi and Wilson [24].

2.4 Employee engagement

Kahn [25] stated employee engagement involves utilizing workers' abilities in their job tasks, demonstrated through their physical, cognitive, and emotional actions. Employee engagement implies being physically present at work and participating in various activities. An organization must succeed amid increasingly fierce competition and growing external uncertainty. After all, employee engagement reduces the companies' challenges during economic volatility and promotes future growth [26].

2.5 Leadership style

Mullins and Christy [27] defined leadership style as the specific method leaders employ and how they behave toward their subordinates. Leadership style is a series of methods or unique ways for leaders to influence their subordinates in achieving set vision or goals. Bandura and Schunk [28] reported that this variable is crucial to produce a conducive workplace because employees respond to their organization based on the leaders' values, emotions, attitudes, and behaviors. Past research studied many leadership styles, but this research is limited to four types: authoritarian, democratic, laissez-faire, and bureaucratic. Additionally, the research set this variable as a dummy in the statistical approach due to possible changes based on situational contexts.

Authoritarian leadership reflects a process in which leaders wield significant power and authority and often impose their will on others. This leadership style reflects a dominant attitude causing a different team morale and effectiveness level [29]. Meanwhile, a democratic leader invites employees and team members to share their input on decisions but ultimately retains decision-making. This technique enables these individuals to take control of their destinies and promotions and are motivated to work hard instead of being financially rewarded [30]. The laissez-faire management approach allows employees to work freely without interference and does not establish specific goals [30]. Bureaucratic leadership is associated with procedures or policies; if the rules do not protect them, leaders can refer to their superiors [31].

2.6 Conceptual framework and hypothesis development

2.6.1 Framework and hypothesis for corporate governance and employee engagement

Good corporate governance fosters a healthy working environment, which increases employees' productivity level of attachment. Indonesia's Committee for Corporate Governance, or KNKG [16], reported that this variable adheres to five fundamental principles: transparency, accountability, responsibility, independence, and fairness.

Preliminary studies reported that consistent and transparent communication increases employee engagement [32]. Transparency fosters trust between employees and management, thereby causing them to become more engaged [33]. Men and Hung-Baesecke [32] reported that accountability positively affects employee engagement. Chaudhary [34] stated that leaders optimize corporate social responsibility as a talent management program to develop a committed workforce. In the pillar of independence, when a corporation is managed professionally without the intervention of other parties, better strategic decisions are achieved [35], and employees' wishes are considered [36]. O'Connor and Crowley-Henry [37] reported that procedural, interactional, and distributive justice affect employee engagement in the pillars of fairness. In addition, the study of Mura [38] concluded that more than 90% of small business people believe a firm culture that values ethics aids employee retention. This finding strengthens the necessity of good corporate governance practices in boosting employee engagement.

The following hypothesis was derived from the above discussion:

H1: Corporate governance impacts employee engagement in a positive and significant way.

2.6.2 Framework and hypothesis for internal control and employee engagement

Strict internal control supports achieving corporate goals and reduces uncertainty generally detested by employees. Mutnuru [11] stated that implementing this variable is significantly related to employee engagement. Meijman and Mulder [12] further noted that an exemplary IC implementation contributes to a conducive work environment. Meanwhile, Kumar and Sia [39] reported that the work environment positively affects employee engagement. In such an environment, tasks are more likely to be completed successfully, reducing work goals and thereby making the employees feel more involved with the organization [40].

The following hypothesis was derived from the above discussion:

H2: Internal control impacts employee engagement in a positive and significant way.

2.6.3 Framework and hypothesis for corporate reputation and employee engagement

A company's reputation is essential and boosts employees' confidence in their working environment. This variable tends to affect their confidence in achieving sustainability, work comfort, etc. Ali and Ali [13] stated that corporate reputation significantly affects employee engagement. Peer the study by Men [41], this statement shows that it significantly and positively affects employee engagement [42]. Perceived corporate reputation is an essential predictor of employee engagement. It reduces employee fatigue and the intention to resign, even in

unstable working conditions [15]. Furthermore, companies with good reputations have advantages in hiring employees due to higher quality job applicants [43].

The following hypothesis was derived from the above discussion:

H3: Corporate reputation impacts employee engagement in a positive and significant way.

2.6.4 Moderating role of leadership style in corporate governance

A leader initiates corporate governance, and it simply indicates that the leadership style is likely to affect its implementation. The transformational leadership style is most likely to employ a type of corporate governance that pays attention to the employees' opinions. Meanwhile, authoritarian leadership styles conduct corporate governance with little concern for employee opinions. This fact raises the question of whether leadership style can moderate corporate governance's impact on staff engagement. Angus-Leppan et al. [44] reported that leadership style affects corporate social responsibility and is part of corporate governance. This finding is vital in guiding corporate governance practices and strongly influences related matters [45]. Deliu [46] reported that corporate governance ensures everybody benefits from using companies' resources. Good leadership is vital to successfully implementing corporate governance [47]. A good leader creates systematic corporate governance that is easy for the employees to adhere [48], ultimately affecting employee engagement with the firm [33].

The following hypothesis was derived from the above discussion:

H4: Leadership style's positive and significant moderating role in corporate governance on employee engagement.

2.6.5 Moderating role of leadership style in internal control

Leaders decide how the corporation executes internal control, so their leadership style significantly dictates daily internal control practice. If the style fits the situation and condition of the organization, then it makes internal control effective and efficient [49]. This thought aligns with the finding of Dal Mas and Barac [50] that leadership styles affect internal control, especially internal audit effectiveness. Aziz [51] also found that, especially in democratic leadership, it will lead to engagement because they listen to employee voices. Meanwhile, internal control positively impacts employee engagement [11]. Good leaders tend to possess a robust internal control system [52], affecting employee engagement [37].

The following hypothesis was derived from the above discussion:

H5: Leadership style's positive and significant moderating role in internal control on employee engagement.

2.6.6 Moderating role of leadership style in corporate reputation

Leadership quality indicates how good the company's reputation is. The transformational leadership style makes the corporate reputable for being friendly to its employees. In contrast, authoritarian leadership enables strong corporation and reputation [52]. Alfalah [53] stated that both leadership skills positively affect corporate reputation. Stavrinoudis and Chrysanthopoulou [54] further reported that possessing a high charismatic leadership resonates with a significant corporate reputation. Influential and creative leaders with vision are essential in enhancing a company's reputation [55]. They need to understand the different dimensions of a crisis to manage the situation effectively [56]. Preliminary studies stated that corporate reputation positively impacts employee engagement [13]. Based on some literature and opinions, leadership style as a moderating variable affects corporate reputation with employee engagement.

The following hypothesis was derived from the above discussion:

H6: Leadership style's positive and significant moderating role in corporate reputation on employee engagement.

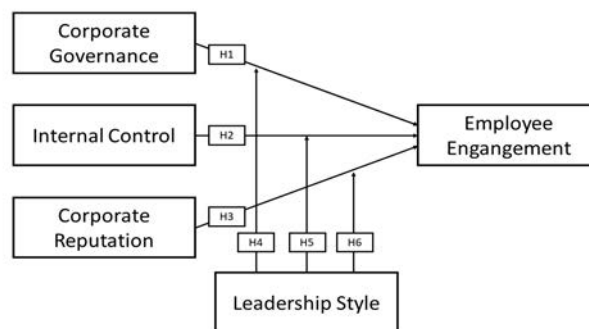


Figure 1 Conceptual framework

Figure 1 explains six hypotheses in this study, with three direct influences of three independent variables on employee engagement and the other three indirect influences of leadership style acting as moderating variables.

3 Methodology

3.1 Sample and data collection

Questionnaires were distributed to forwarders or logistics firms in Indonesia. The firms participating in this research must be the Indonesian Logistics and Forwarders Association (ILFA) members. An online Google Form link was sent to respondents from October 14, 2021, to February 22, 2022. However, of the 3412 companies registered as ILFA members, only 353 were selected. This study used purposive sampling method to select respondents; the population is limited to specific people who can provide the necessary information or meet the

criteria set by the study. The respondents comprised supervisors with at least two years' work experience and graduates with a Diploma 3 (D3) or above. The criteria are compromised because when working for over two years and with better education, respondents are assumed to know better about their working corporate and will have better judgment. It was discovered that, of the 802 respondents from the 380 companies who filled out the questionnaire, only 742 of them from 353 firms were valid based on sampling criteria.

3.2 Data analysis

The research used PLS-SEM with SmartPLS 4.0 software under outer and inner frameworks. The measurement of the outer model connects the latent variable with the manifest. Confirmatory factor analysis (CFA) measured the latent constructs' reliability and validity. Hair et al. [57] stated that the model test consists of convergent and discriminant validities as well as internal consistency reliability. The structural model describes the relationship among variables. Its evaluation consists of R2,

Prediction relevance – PLS predict coefficient, and f2 – effect size.

4 Research results

4.1 Characteristic analysis

Table 1 illustrates the breakdown of respondents' positions divided into five categories: 40.70% of those surveyed worked as a supervisor, 46.63% as a manager, 6.20% as a general manager, 4.99% as a director, and 1.48% as a commissioner. The distribution of respondents by tenure now includes employees with 2 to 5 years of service and employees with more than 5 years of service. Interestingly, 64.29% of respondents have worked for their current employers for 2-5 years, and 35.71% have joined their current organization over 5 years. The respondent's educational background went into three groups: below undergraduate (Diploma), undergraduate, and postgraduate (Master/Doctor) Degrees. Incidentally, 15.23% of the respondents had recently obtained a Diploma 3 degree, 51.89% had a Diploma 4 equivalent degree, and 32.88% were under a Master/Ph.D. qualification.

Table 1 Descriptive analysis (respondents)

Characteristics	Total	Percentage
Working Position		
Supervisor	302	40.70%
Manager	346	46.63%
General Manager	46	6.20%
Board of Directors	37	4.99%
Board of Commissioners	11	1.48%
Total	742	100.00%
Working Period		
Two to five years	477	64.29%
More than five years	265	35.71%
Total	742	100.00%
Recent Education		
Below Undergraduate	113	15.23%
Undergraduate	385	51.89%
Postgraduate	244	32.88%
Total	742	100.00%

Table 2 shows the division of companies in five locations representing the main islands in Indonesia. 84.42% of firms are in Java and Bali, 5.10% in Kalimantan, 5.38% in Sumatra, 3.40% in Sulawesi, and 1.70% in other parts of the country. Respondents from Java and Bali occupied the most significant portion as compared to other areas. These company breakdowns are based on four leadership styles adopted. This category includes

companies that apply democratic, laissez-faire, bureaucratic, and authoritarian leadership styles. Interestingly, 78.19% of companies applied democratic, 3.12% applied laissez-faire, 13.88% applied bureaucratic, and applied 4.82% authoritarian leadership styles, respectively. It showed that most logistics firms in Indonesia adopt a democratic leadership style.

Table 2 Descriptive analysis (company)

Descriptions	Total	Percentage
Company's Location		
Java and Bali	298	84.42%
Kalimantan	18	5.10%
Sumatra	19	5.38%
Sulawesi	12	3.40%
Others	6	1.70%
Total	353	100.00%
Leadership Style Implemented		
Democratic	276	78.19%
Laissez-faire	11	3.12%
Bureaucratic	49	13.88%
Authoritarian	17	4.82%
Total	353	100.00%

4.2 Common method bias

PLS-SEM states that common method bias will happen if the measurement method influences a value in SEM [58]. This step was done to make sure the collected data was not biased. The test was done by measuring the value of

collinearity statistics (VIF) in the inner VIF value. If the VIF value is higher than 3.3, then we can conclude that there is an indication of common method bias. Meanwhile, if VIF numbers are 3.3 or lesser, we can conclude the model is not under a common bias effect [59]. Table 3 validates that all constructs are common method bias-free.

Table 3 Common method bias

	CG	CR	EE	IT
CG		3.212	3.105	3.274
CR	3.244		3.273	3.204
EE	3.237	3.109		3.295
IC	3.236	3.123	3.197	

Based on Table 3, the VIF in each variable produces a value < 3.3, meaning that the data was not symptoms-biased.

AVE value > 0.5 and a loading factor higher than 0.7, meaning all indicators were valid to measure each latent variable [60]. From the reliability test results, it is evident that all latent variables have CR (Composite Reliability) and CA (Cronbach Alpha) values > 0.7 and are declared reliable [59]. This fact shows that all the dimensions used as measuring tools are valid and appropriate for each construct.

4.3 Outer model analysis

Table 4 shows the data processing results where all indicators of dependent and independent variables have an

Table 4 Convergent validity and reliability test

Constructs	Indicators	Loading Factor	AVE	CA	CR
Corporate Governance	X.1.1	0.879	0.757	0.920	0.940
	X.1.2	0.869			
	X.1.3	0.867			
	X.1.4	0.849			
	X.1.5	0.885			
Internal Control	X.2.1	0.823	0.754	0.918	0.939
	X.2.2	0.881			
	X.2.3	0.877			
	X.2.4	0.902			
	X.2.5	0.857			
Corporate Reputation	X.3.1	0.785	0.677	0.904	0.926
	X.3.2	0.843			
	X.3.3	0.810			
	X.3.4	0.857			
	X.3.5	0.842			

Constructs	Indicators	Loading Factor	AVE	CA	CR
	X.3.6	0.796			
	Y.1.1	0.903			
	Y.1.2	0.900			
	Y.1.3	0.847			
	Y.1.4	0.877			
	Y.1.5	0.827			
Employee Engagement	Y.1.6	0.890	0.773	0.971	0.974
	Y.1.7	0.881			
	Y.1.8	0.907			
	Y.1.9	0.891			
	Y.1.10	0.860			
	Y.1.11	0.885			

4.5 Inner model analysis

The coefficient determination value (R2) in Figure 2 shows that three independent variables strongly

contributed (0.800) to employee engagement. In other words, it explains 80% of these constructs.

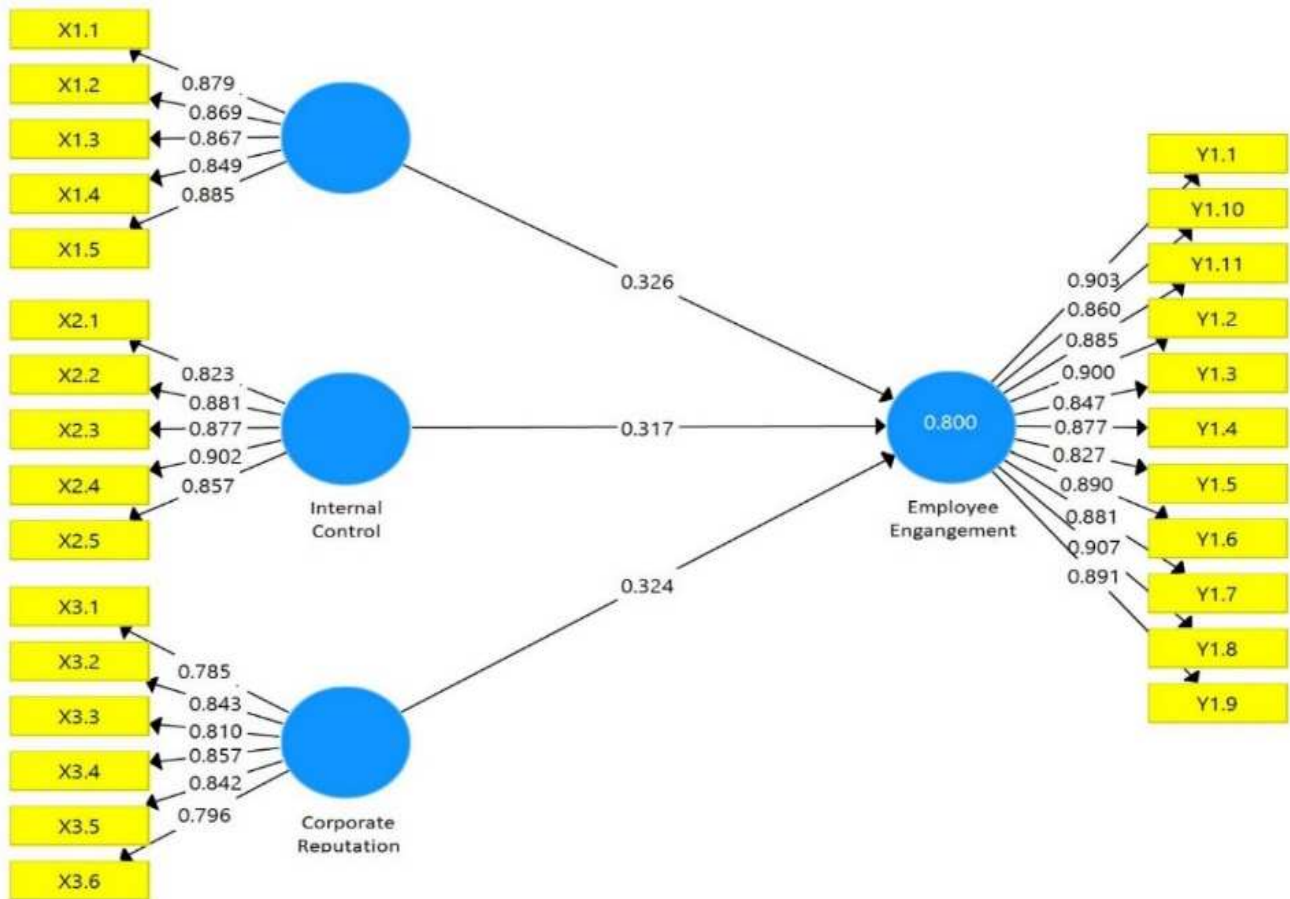


Figure 2 Structural model without moderation

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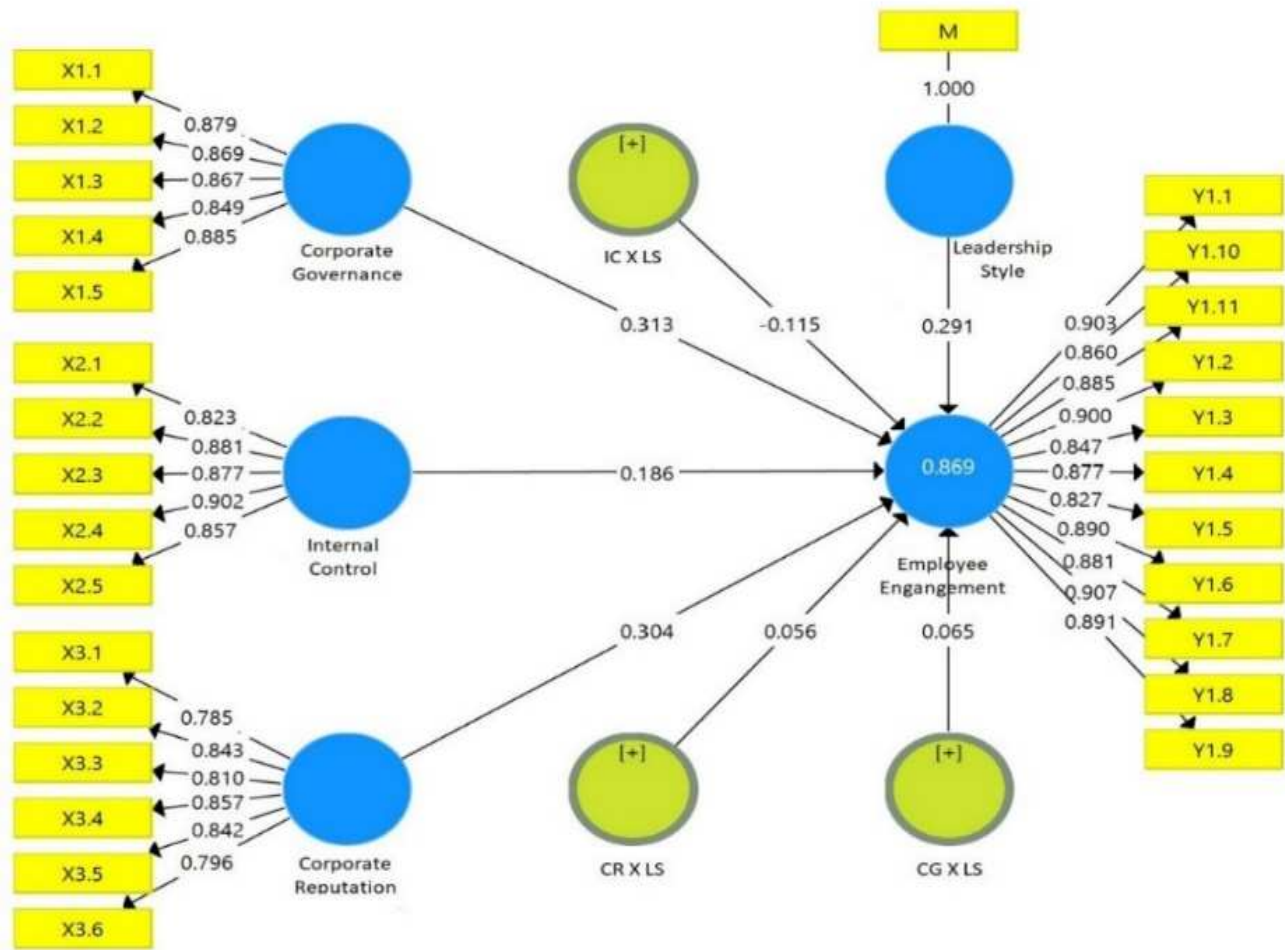


Figure 3 Structural model with moderation

The predictive-relevance value was tested using the PLSpredict technique to illustrate that each exogenous variable's indicators can predict the endogenous attributes.

The model is presumed to have good predictive power when the RMSE value in PLS is less than LM [59]. Table 5 illustrates the PLSpredict figures.

Table 5 PLSpredict analysis

Dimension	PLS			LM			PLS-LM		
	RMSE	MAE	Q²_predict	RMSE	MAE	Q²_predict	RMSE	MAE	Q²_predict
Y.1.1	0.466	0.360	0.688	0.468	0.360	0.686	-0.002	0.000	0.002
Y.1.2	0.541	0.419	0.623	0.555	0.416	0.604	-0.014	0.003	0.019
Y.1.3	0.518	0.416	0.611	0.524	0.416	0.602	-0.006	0.000	0.009
Y.1.4	0.530	0.434	0.615	0.539	0.436	0.603	-0.009	-0.002	0.012
Y.1.5	0.561	0.452	0.552	0.581	0.462	0.520	-0.020	-0.010	0.032
Y.1.6	0.483	0.387	0.620	0.494	0.384	0.603	-0.011	0.003	0.017
Y.1.7	0.490	0.391	0.600	0.502	0.398	0.580	-0.012	-0.007	0.020
Y.1.8	0.501	0.403	0.633	0.515	0.409	0.613	-0.014	-0.006	0.020
Y.1.9	0.593	0.438	0.609	0.596	0.438	0.605	-0.003	0.000	0.004
Y.1.10	0.495	0.371	0.614	0.519	0.381	0.574	-0.024	-0.010	0.040
Y.1.11	0.584	0.429	0.550	0.595	0.446	0.533	-0.011	-0.017	0.017

Note: The letter in italics shows that RMSE PLS subtracts RMSE LM

The model is declared to have good predictive power because Table 5 data shows RMSE value lesser than the LM.

Table 6 f^2 – Effect size analysis

Path	F-Square	Category
CG on EE	0.171	Moderate
IC on EE	0.157	Moderate
CR on EE	0.155	Moderate

The f^2 test calculates each effect of exogenous variables on the endogenous variable. Based on the results of the f^2 – effect size calculation in Table 6 which shows the F-square (f^2) value is within the range of 0.15 to 0.34, it means the exogenous ones have moderate effects on the endogenous variable.

4.6 Hypothesis testing

Table 7 shows that hypotheses 1, 2, 3, 4, and 6 were accepted. On the other hand, the fifth hypothesis implied that leadership style did not enhance internal control’s effect on the dependent variable in a positive and significant way.

Table 7 Hypothesis testing

Hypothesis	Path (Relationship)	Path Coefficient	t-value	P Values	Hypothesis Conclusion
H1	CG on EE	0.326	7.004	0.000	Accepted
H2	IC on EE	0.317	5.621	0.000	Accepted
H3	CR on EE	0.324	5.117	0.000	Accepted
H4	LS to CG on EE	0.065	1.970	0.025	Accepted
H5	LS to IC on EE	-0.115	3.772	0.000	Rejected
H6	LS to CR on EE	0.056	2.004	0.023	Accepted

5 Discussion

5.1 The discussion of hypothesis 1

The proven first hypothesis implies the better the corporate governance practice, the more employees are engaged. Good corporate governance informs employees of the establishment’s rules, vision, and mission. This fact means companies need to ensure the value of their good corporate governance is following employee values. This fact aligns with the goal-setting theory that having specific and ambitious goals leads to enormous performance [5]. An increase in performance causes employees to feel comfortable at work, ultimately increasing their engagement. This result aligns with the research findings by Vogelsang et al. [61], and Yue et al. [33] on the ability of good governance to increase employee engagement through the implementation of the transparency dimension. Also, implementing accountability in good corporate governance increases employee engagement. When companies carry out their responsibilities with an excellent corporate governance dimension, they create a sense of pride in employees, ultimately increasing their engagement [62]. This fact is in line with the studies by Slåtten and Mehmetoglu [35] and Bandura and Lyons [36], those independent organizations carry out certain activities without being influenced by outsiders, thereby increasing the employees’ sense of security at work. O’Connor and Crowley-Henry [37] and Saratun [10] stated that fair corporate practice must provide equal opportunities to every employee to boost their engagement.

5.2 The discussion of hypothesis 2

The second hypothesis proves that a properly implemented Internal Control system positively and significantly affects Employee Engagement. An exemplary implementation of this process leads to fairness and work effectiveness, thereby boosting employee comfort and

raising engagement. This fact means the company needs to strictly implement its internal control because it leads to the feeling of being treated fairly and thus increases employee engagement. This result aligns with Maslow’s Theory, whereby people have needs, with a sense of fairness and security at the second level [8]. Meanwhile, when these needs are met, it leads to higher engagement.

Mutnuru [11] stated that internal control implementation directly relates to employee engagement level. This finding aligns with Meijman and Mulder [12] and Kumar and Sia [39] that implementing good internal control creates a more productive work atmosphere that keeps the employees engaged. Furthermore, Bakker [40] stated that a positive work environment where the employees feel involved and proud leads to more robust financial performance and lower employee resignations. The environment makes them feel happier, thereby leading to increased organizational performance and productivity. Saratun [10] stated that good internal control within the corporation increases the level of trust and fairness, which also affects employees’ perception of the company.

5.3 The discussion of hypothesis 3

The third hypothesis shows corporate reputation positively and significantly impacts the dependent variable. This statement means if a company’s reputation improves, its employees will be more engaged. Employees need material and non-material benefits, such as a sense of pride. Besides, any company with good branding also possesses better employee retention [14]. This fact means the company always needs to maintain its reputation positively because it leads to employee pride and engagement. This fact aligns with the expectancy theory that a person tends to act a certain way toward others [15]. Working for a reputable company boosts the employees’ pride, which triggers engagement. This fact is consistent

with Maslow's hierarchy theory that employees have needs, with pride at the fourth level [8]. The studies by Ali [13], Men [41], Shirin [42], Shirin and Kleyn [14], and Şantaş et al. [63] stated that a positive corporate reputation makes staff more engaged. Furthermore, Ali et al. [64] reported that a good corporate reputation reduces employee fatigue, even in unstable working conditions, including the willingness to resign. This fact is under the study by Gatzert and Schmit [43] that companies with good reputations are advantageous in hiring employees with higher qualifications.

5.4 The discussion of hypothesis 4

The fourth hypothesis demonstrates that leadership style reinforces corporate governance's effect. This fact suggests that a more decisive leadership style will further boost corporate governance's effect on making staff feel more attached to the organization. This fact means leaders need to retain the style of leadership implemented because it positively affects how the corporate is governed and affects employee engagement. The application of leadership style shall follow the characteristics of an organization. This statement is consistent with the contingency theory that the best course of action is to rely on changes in internal and external situations [22]. However, applying a democratic leadership style is currently better because it makes the leader listen to input from subordinates capable of improving corporate governance, which aligns with the study done by Iqbal et al. [65]. This variable helps to guide corporate governance practices [46,66], leading to employee engagement [32,34]. O'Connell [47] reported that leadership style is the primary key to successfully implementing corporate governance frameworks, which tends to increase employee engagement [38]. Corporate governance's influence over employee engagement is enhanced by leadership style [66].

5.5 The discussion of hypothesis 5

The fifth hypothesis demonstrates that the leadership style significantly reduces the impacts of internal control on employee engagement. Each has its advantages and disadvantages in influencing internal control. However, the stronger the style, the weaker the internal control, so leadership style changes according to the situation and condition. For example, some need to be given strict rules, freedom, and greater listening opportunity. Ideally, the authoritarian leadership style strengthens the quality of the control mechanism.

On the contrary, the influence of the democratic style on the implementation of internal control significantly affects employees' competence and ability to make decisions. In a democratic leadership style, there is usually a conflict between the corporation and the interests of every individual. The leader's willingness to appreciate employees' feedback and make correct decisions is essential to maintaining good internal control. Therefore,

the democratic approach enables leaders to make firm decisions and implement internal control more effectively, and this result aligns with the finding of Iqbal et al. [65]. Grobler [49] and Dal Mas and Barac [50], stated that each leadership style influences corporate internal control.

Meanwhile, Mutnuru [11], and Kumar and Sia [39], reported that internal control makes staff feel more attached to their employer. This fact means leaders need to implement a compatible leadership style, mainly because this study was conducted in Indonesia, known for its diverse cultures; thus, the requirement of each individual in the company is different. The democratic leadership style became one of the best to implement because of its willingness to appreciate employees' feedback.

5.6 The discussion of hypothesis 6

The sixth proven hypothesis means that a stronger leadership style will moderate corporate reputation's effect on the dependent variable. The leader's activity affects the firm's reputation and staff engagement. These include that the leaders' coaching skills have pros and cons impacts on staff turnover intention and happiness, respectively, leading to employee engagement [33]. Each type of leadership style gives the corporation a different reputation. For instance, the authoritarian leadership style creates the impression of democratic safety and comfort, while Laissez-faire provides the trust with the impression of strict rules. This fact aligns with Men and Stacks [52] that leadership styles increase employee engagement depending on their application and portray different reputations. This means that leaders must implement their leadership to the extreme to lead to a more substantial reputation and employee engagement. Men and Stacks [52] and Dutot [67] stated that each leadership style affects employees' perceptions of an organizational reputation.

Meanwhile, Ali and Ali [13], Men [41], and Shirin [42] reported that corporate reputation has a direct effect on employee engagement. The findings also align with Olmedo-Cifuentes and Martínez-León [68] that a participatory and competitive leadership style positively affects employees' views of corporate reputation. According to Alfalah [53], wise leaders can quickly adopt different leadership styles in response to different situations. Previous results supporting this study by Lee [55] show that successful companies depend on influential and creative leaders with a vision to enhance their reputations.

6 Conclusion

In summary, research results have shown that good corporate governance positively and significantly increases employee engagement. The strict internal control practice also positively and significantly improved employee engagement. Similarly, an excellent corporate reputation was also proven to positively and significantly enhance employee engagement. Senior management teams in logistics companies in Indonesia need to put serious effort

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into ensuring good governance practices and strict control programs in their respective firm to deliver reliable and trustworthy financial results and set up a more solid staff engagement level. As for corporate reputation, every employee must ensure the company's image is kept safe by doing all company activities per law and regulations.

The study also revealed that leadership style was influential in improving corporate governance and reputation's influences on employee engagement. On the contrary, it decreased internal control's effect on employee engagement. Indonesian logistics industry leaders must determine the most suitable leadership style under different conditions. This fact is because no single leadership style is compatible with all situations. There must be a balance among the selected leadership types to ensure a better engagement level. Finally, senior management teams will have to see a more comprehensive approach from a human resource perspective and accounting and business commercials to improve employee engagement quality in the office.

7 Limitations and future research

The present study only used four variables to discover factors affecting employee engagement in Indonesian logistics companies. There could be more variables to study their influence on employee engagement. Therefore, future studies must use additional or new variables to enrich prospective findings. Also, while this study was conducted only in the logistics industry, employee engagement may look different in other sectors. Therefore, future research can choose other various industries to test the research's generalizability effectively. The research also does not explicitly focus on groups of generations such as boomers, millennials, and generation Z. Future studies can use this room better to understand different levels of employee engagement among generations.

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The use of mobile applications in logistics of services

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Abstract: The article focuses on the importance of mobile applications in enterprises with a focus on logistics in the service sector. In the theoretical part, individual software applications in the field of occupational health and safety, fire protection, which are used in Slovakia and the Czech Republic are clearly described. The article contains a brief overview of the legislative regulations on the basis of which the obligations for management decisions in enterprises arise. A telephone survey was conducted in 110 micro, small and medium-sized enterprises between 2022 and 2023 in order to determine the use of software solutions in ensuring the fulfilment of obligations in the field of occupational safety and health and fire protection. To collect data, research questions were set and a questionnaire was developed, which included 6 merit questions, identification questions and a specific question aimed at finding out the prioritisation of the most preferred mobile application features in the study area. The questions were closed-ended, with options where the respondent could choose only one answer. SPSS for Windows version 21.0 was used for statistical analysis and processing of the collected data. We used methods of statistical description, analysed using relative abundance, arithmetic mean, standard deviation and median. At the level of statistical inference, we used chi-square goodness-of-fit tests to analyse categorical variables. We also used nonparametric tests, Friedman analysis of variance, 3D pie charts, and 3D group bar charts. We found that business representatives had a significantly higher preference for the functionality "record of initial and recurrent BOZP and PO training", followed by the second most preferred functionality "OSH inspections and fire prevention inspections". The research focused on logistics enterprises.

1 Introduction

Fulfilment of obligations in the area of safety and health protection at work and fire protection are important preventive measures for the protection of life, health and property of persons. The aim of this article is to point out the possibilities of simplifying the fulfilment of the above obligations. Our first step is theoretical research, in which we describe the possibilities of the current software security of services of safety and health protection at work and fire protection (hereinafter referred to as BOZP and PO). We have found that there are specialised software systems that primarily deal with either the BOZP issue or the PO issue separately. When analysing the offer, our aim was to find out what mobile applications specialised companies offer. We found that in Slovakia and the Czech Republic, there is an insufficient offer of mobile applications that would integrate the management of the fulfilment of BOZP and PO obligations. In the next theoretical part, we describe the legislative regulations, in the field of BOZP and PO, which impose obligations on enterprises, which the enterprise is obliged to monitor and subsequently ensure at specified time intervals. We primarily deal with national legislation valid on the territory of the Slovak Republic. Based on the findings of the theoretical part, we established research questions and research hypotheses. We also developed a questionnaire and conducted a questionnaire survey in micro, small and

medium-sized enterprises. Our goal is to point out the insufficient offer of mobile applications that would integrate the fulfilment of obligations in the field of BOZP and PO. Determination of the prioritisation of the functionality of individual applications, which points to possible problem areas in the fulfilment of BOZP and PO obligations. We also point out the demand of enterprises for the mentioned mobile applications.

2 Theoretical research

2.1 Availability of BOZP and PO software applications in the Slovak and Czech Republics

Modern software solutions take into account the requirements that are given by the individuality of individual processes in companies. Software solutions must be adapted to the legislative requirements of each state. This means that the internal legislation of individual states differs. Therefore, even software solutions can have different requirements for individual duties. In Slovakia, there are many companies that deal with the development and application of software in the field of safety and health protection at work and fire protection.

The company Besoft offers BTS software, which consists of 14 modules.

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The modules themselves are divided into:

1. Safety and health protection at work (BOZP),
2. Fire protection (PO),
3. Environment,
4. Civil protection,
5. Employees,
6. Technical equipment,
7. Chemical substances,
8. Risks,
9. Waste,
10. BOZP management system,
11. Tests [1].

The goal is to provide organisations with a complex of services from selected areas for the fulfilment of legislative obligations, which, last but not least, monitor the protection of life and property. When developing the aforementioned software modules, the long-term requirements of individual subjects were taken into account.

BOZP ASPI primarily focuses on searching for all regulations, court decisions and copyrighted comments, various monographs, models, as well as other translated legislation, which will enable the user to orientate himself/herself in the legislation. It provides time-saving, clarity and simplicity.

It is divided into BOZP ASPI and BOZP ASPI Profit, which contains comments, samples and English translations [2].

The BWSS software allows the user the possibility of advanced and highly efficient processing of the summary agenda of safety and health protection at work. It enables the linking of the training agenda as well as the revision agenda. It includes the modules:

1. The basic package of services,
2. Work safety notebook,
3. Reserved technical equipment,
4. Personal protective work equipment,
5. Administration,
6. Protection of personal data [3].

The software, which integrates issues of occupational safety and health and fire protection and is easy to use intuitively, is offered by the company Traiva. A new feature is the processing of training through Safetutor. It is a training with a test in 3D at the world level. It offers various levels of software solutions aimed at professionally qualified persons, manufacturing and non-manufacturing companies with over 50 employees, non-manufacturing companies - offices, small manufacturing companies, medical facilities, doctors, schools, authorities [4].

It must be said that the Ministry of the Interior of the Slovak Republic employs various professions despite the fact that it is a non-production organisation. For this reason, it is necessary that all specifics are taken into account when implementing the software module.

Each implementation of any ERP system in an organisation represents a fundamental change in its functioning and organisation. Only a correctly set course

of the implementation process will guarantee the correct integration of the information system with the company [5].

The information system of the supplier method of revision has its fundamental justification and brings time savings and the seamless transfer of information between individual subjects performing tasks in the area of safety and health protection at work, as well as work inspections. The issue of revision and controls should be identified with the idea of Industry 4.0 [6,7].

The goal of digitisation in logistics is to speed up all processes and make them more accurate and smoother [8]. In the processes of activity of fire protection technicians, accuracy means reducing the risk of fires to a minimum. Innovations play a significant role in the success of the company as well as central state administration bodies.

Nowadays, innovations are becoming an important factor in the success of the company. Their legal implementation can put the company ahead of the competition [9].

Given that the key drivers of a logistics system include products, preferences of customers, technology innovation, globalisation, sustainability, infrastructure, and cost, it can be assumed that a logistics service can create a competitive niche in terms of how it can respond to the key drivers [10].

Based on experience using mobile solutions and various hardware suites to support logistics and transport processes such as booking of vehicles, invoicing, and payment services, tracking of deliveries, exchange of typical sets of information between participants [11].

2.2 Legislative obligations

Operation of individual objects and mandatory conditional legislative conditions in the area of fire protection. The basic law in the field of fire protection is Act No. 314/2001 Coll. on fire protection and on the amendment of some laws as amended by later rewrites [12]. The implementing decree of this law is the Decree of the Ministry of the Interior of the Slovak Republic no. 121/2002 Coll. on fire prevention [13].

Fire equipment division, fire engineering equipment (PTZ):

- a) Fire extinguishers,
- b) Fire shutters,
- c) Equipment for extinguishing sparks in PD, equipment for the supply of water for extinguishing fires, equipment for the permanent supply of electricity in the event of a fire, evacuation and emergency lighting, other equipment for the evacuation of people and intervention [14].

Fire engineering is stable extinguishing equipment and semi-stable extinguishing equipment. There are also devices for removing combustion products and electric fire alarm along with voice fire alarm [14].

In our article, we will deal with the records of fire extinguishers, fire shutters, hydrants and electric fire

alarms and their central voice offices. We will describe which necessary data the operator is obliged to register.

Basic legislative regulations in the area of:

- a) Fire extinguishers are a Decree of the Ministry of the Interior of the Slovak Republic no. 347/2002 Coll. on the properties and conditions of operation, marking and ensuring regular inspection of fire extinguishers [14].
- b) Fire shutters are a Decree of the Ministry of the Interior of the Slovak Republic no. 478/2008 Coll. on the properties, specific conditions of operation and ensuring regular inspection of the fire shutter [15].
- c) Hydrants are a Decree of the Ministry of the Interior of the Slovak Republic no. 699/2004 Coll. z on the provision of water for firefighting [16].
- d) The electronic fire alarm is a Decree of the Ministry of the Interior of the Slovak Republic no. 726/2002 Coll., which establishes the properties of an electric fire alarm, the conditions for its operation and ensures its regular inspection [17].

The Ministry of the Interior of the Slovak Republic is the operator of facilities, where facilities are operated by the economy section and individual support centres located in regional cities [18].

The fire technician and the designated operator of the facility need to know the individual fire equipment for their work. Unlike reserved technical equipment [19], they are usually characterised by a larger number. The basic knowledge that the operator and fire technician must know includes, in particular, data on the location, data on the type of fire equipment, inspection interval, revision, date of the last and subsequent inspection, the validity of the inspection, or a higher test, requirements for ensuring inspection, or service. For this, it is necessary to have accurate records of employees, data on initial training in the fire protection section, data on repeated training in the fire protection section, and a schedule of preventive fire inspections. However, the problem may arise for operators with a higher number of employees or facilities. For operators with a lower or low number of employees or facilities, the process of securing mandatory obligations is easier. In this case, there is easier control and provision of supplier assurance of training, inspections and service. It is also necessary to draw attention to the problem of public procurement of these services, as state organisations are obliged to proceed according to the Public Procurement Act no. 343/2015 Coll. on public procurement and on amendments to certain laws [20]. Public procurement is controlled by the Public Procurement Office. It is a process that is of interest to the public, the media and the like. Therefore, it is necessary for this process to be transparent and in accordance with individual legislative standards [21,22]. However, this requires that the individual descriptions of the objects of the contracts be determined as accurately as possible. In the case of central public procurement, precisely the data generated by the software

will simplify the public procurement process. Also, the entire process of securing individual inspections according to the above-mentioned legislative regulations. In this, the software can enter the process, which accurately evaluates the required data and makes the process more transparent. As we have mentioned, fire protection processes are guided by many legislative regulations of different legal forces, which follow the main purpose of protecting people and property from fires. The main purpose is the protection of human life, followed by the protection of property.

3 Methodology

3.1 Composition of the research group

We conducted a questionnaire survey in the Slovak Republic in enterprises engaged in the provision of services.

The survey took place in the regions (a total of 110 enterprises):

1. Bratislava region - 20 surveyed enterprises,
2. Trnava region - 10 surveyed enterprises,
3. Nitra region - 15 surveyed enterprises,
4. Trenčín region - 15 surveyed enterprises,
5. Banská Bystrica region – 10 surveyed enterprises,
6. Žilina region - 15 surveyed enterprises,
7. Prešov region - 10 surveyed enterprises,
8. Košice region - 15 surveyed enterprises.

Representatives of micro-enterprises predominated in the research group, representing up to 60% of the research group (N = 66). In terms of number, they were followed by representatives of small enterprises, who made up 37.3% of the research group (N = 41). The least numerous group were representatives of medium-sized enterprises, which represented only 2.7% of the research group (N = 3). The composition of the research group in terms of enterprise size is summarised in Table 1.

Table 1 Composition of the research group in terms of enterprise size (N = 110)

Question	Answers	N	N _R
Size of your enterprise	1 to 9 (micro-enterprises)	66	60.0
	10 to 49 (small enterprises)	41	37.3
according to the number of employees	50 to 249 (medium-sized enterprises)	3	2.7

3.2 Data collection methods

In order to collect the data necessary to answer our research questions, or verification of our research hypotheses, we compiled a questionnaire that included 6 items.

The first questionnaire item, "The size of your enterprise according to the number of employees", allowed us to analyse what part of our research group is micro-enterprises, small enterprises and medium-sized enterprises.

With the help of the second item, "Do you use a software solution for securing BOZP and PO services?",

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we determined the rate of use of the given PCs, or mobile software solutions.

The third item, "What is your attitude towards mobile applications whose solutions simplify the management of the fulfilment of obligations?" allowed us to identify the attitude of enterprises towards the given mobile applications, regardless of whether they currently use the given mobile applications or not.

With the help of the fourth item, "Do you know special mobile applications that would integrate the management of BOZP and PO services?", we investigated the knowledge of enterprises about the existence of the given mobile applications, regardless of whether they currently use the given mobile applications or not.

The fifth item, "If mobile applications that integrate the management of BOZP and PO services were commonly available on the market, would you purchase them?" allowed us to identify the interest of enterprises in the given mobile applications in case of their better availability, and at the same time point out the fact that whether or not the availability of mobile applications is one of the main reasons for not using them.

Within the sixth item, "Which functions should the functionality of mobile applications for the management of BOZP and PO services provide?" the respondents had the task of ranking the individual functionalities of the given mobile applications according to priority, respectively importance, and thus point out the functionalities that would convince enterprises to the highest extent to acquire the given mobile applications.

3.3 *Methods of statistical processing and data analysis*

For the purpose of statistical analysis and processing of collected data, we used the program SPSS for Windows version 21.0.

We analysed the obtained data at the level of statistical description using numerousness (N), relative numerousness (NR), arithmetic mean (AM), standard deviation (SD) and median (Mdn).

At the level of statistical inference, we used chi-square goodness-of-fit tests to analyse categorical variables. Due to the ordinal nature of the remaining variables, we decided to use nonparametric tests, namely Friedman's analysis of variance.

In order to graphically represent the results of the analyses, we used 3D pie charts and 3D group column charts.

4 **Result and discussion**

4.1 *Testing research hypotheses*

RH1: We assume that significantly more micro, small and medium-sized enterprises do not use mobile applications that integrate the management of BOZP and PO obligations.

We verified the assumption that significantly more micro, small, and medium-sized enterprises do not use

mobile applications that integrate the management of BOZP and PO obligations using frequency analysis followed by chi-square goodness-of-fit tests. Frequency analysis enabled us to determine the absolute and relative number of individual responses from enterprise representatives to questions regarding mobile applications for the management of BOZP and PO services. Chi-square goodness-of-fit tests allowed us to determine whether positive and negative answers to individual knowledge questions occurred significantly more often than incorrect answers.

In the case of the question "Do you use a software solution for securing BOZP and PO services?", the results of the frequency analysis showed that the most frequently chosen answer was "Yes, our company has purchased the given software, which is installed on the PC", which was given by up to 40% of respondents. The answer "No, we do not use the given software solutions" was chosen by 31.8% of enterprise representatives. In terms of frequency, the answer "Yes, we use the given software solutions that we have installed in the PC and in the MA" followed, which was given by 14.5% of the respondents. The least frequent was the answer "Yes, we use the given software solutions in MA", which was chosen by only 13.6% of enterprise representatives. It can be summarised that only 28.2% of enterprises used mobile applications that integrate the management of BOZP and PO obligations. The remaining 71.8% of enterprises did not mention the use of the mentioned mobile applications. According to the results of the chi-square goodness-of-fit test, the mentioned difference was statistically significant, $\chi^2 = 20.945$, $p < .001$. From the above, it follows that the number of enterprises that use mobile applications integrating the management of BOZP and PO obligations is significantly lower than the number of enterprises that do not use these mobile applications.

In the case of the question "What is your attitude towards MA, the solutions of which simplify the management of the fulfilment of obligations?", the results of the frequency analysis showed that the most frequently chosen answer was "Our company has a positive attitude towards MA, that's why we mainly use paid versions", which was given by 62.7% of respondents. 29.1% of enterprise representatives chose the answer "Our enterprise does not use MA". In terms of frequency, the answer "Our enterprise does not have a positive relationship to MA" followed, which was given by 5.5% of respondents. The least frequent answer was "Our enterprise only uses free versions", which was chosen by only 2.7% of enterprise representatives. It can be summarised that up to 65.5% of enterprises have a positive attitude towards mobile applications that integrate the management of BOZP and PO obligations. The remaining 34.5% of enterprises had a negative attitude towards the use of the mentioned mobile applications. According to the results of the chi-square goodness-of-fit test, the mentioned difference was statistically significant, $\chi^2 = 10.509$, $p = .001$. It follows from the above that the number of enterprises that have a

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positive attitude towards mobile applications integrating the management of BOZP and PO obligations is significantly lower than the number of enterprises that have a negative attitude. The described finding supported our research hypothesis.

In order to gain insight into the reasons for not using mobile applications integrating the management of BOZP and PO services, we decided to also analyse the answers of enterprise representatives to questions regarding their attitude towards these mobile applications, their level of knowledge of these applications, and also their potential future interest in purchasing these mobile applications under the assumption of their better availability.

In the case of the question, "Do you know a special MA that would integrate the management of BOZP and PO services?", the results of the frequency analysis showed that the most frequently chosen answer was "Yes, I know", which was given by up to 80.9% of respondents. Only 19.1% of enterprise representatives chose the answer "No, I don't know". According to the results of the chi-square goodness-of-fit test, the mentioned difference was statistically significant, $\chi^2 = 42.036$, $p < .001$. From the above, it follows that the number of enterprises that are aware of special mobile applications integrating the management of BOZP and PO obligations is significantly higher than the number of enterprises that are not aware of these applications.

In the case of the question "If MA, integrating the management of BOZP and PO services, were commonly available on the market, would you purchase them?", the results of the frequency analysis showed that the most

frequently chosen answer was "Yes, I would purchase", which was stated by up to 78.2% of respondents. The answer "I would decide later" was chosen by 13.6% of enterprise representatives. In terms of frequency, the answer "We have purchased it" followed, which was given by 8.2% of respondents. The least frequent answer was "No, I would not purchase", which was chosen by none of the enterprise representatives (0%). It can be summarised that up to 86.4% of enterprises would acquire mobile applications that integrate the management of BOZP and PO obligations, assuming their better availability. The remaining 13.6% of enterprises would only consider buying them. According to the results of the chi-square goodness-of-fit test, this difference was statistically significant, $\chi^2 = 58.182$, $p < .001$. It follows from the above that the number of enterprises that would acquire mobile applications integrating the management of BOZP and PO obligations is significantly lower than the number of enterprises that would only consider it, while there was no enterprise in our research group that would certainly not purchase such a mobile application.

It can be summarised that the number of enterprises that use mobile applications integrating the management of BOZP and PO services is significantly less than the number of enterprises that do not use these applications, but the reason is neither a negative attitude, nor ignorance, nor lack of interest in the case of better availability. The above indicates that the main reason for these findings is the unavailability of the given mobile applications. The results are summarised in Table 2, Table 3 and graphically represented in Figure 1.

Table 2 Frequency analyses of responses of respondents from among micro, small and medium-sized enterprises to questions regarding the use of mobile applications for the management of BOZP and PO services (N = 110)

Questions	Answers	N	N _R
Do you use a software solution for securing BOZP and PO services?	<i>Yes, our company has purchased the given software, which is installed on the PC</i>	44	40.0
	<i>Yes, we use the given software solutions that we have installed on the PC and in the MA</i>	16	14.5
	<i>Yes, we use the given software solutions in MA</i>	15	13.6
	<i>No, we do not use these software solutions</i>	35	31.8
What is your attitude towards MA, the solutions which simplify the management of the fulfillment of obligations?	<i>Our company has a positive attitude towards MA, which is why we mainly use paid versions</i>	69	62.7
	<i>Our enterprise does not use MA</i>	32	29.1
	<i>Our enterprise uses only free versions</i>	3	2.7
	<i>Our enterprise does not have a positive relationship with MA</i>	6	5.5
Do you know a special MA that would integrate the management of BOZP and PO services?	<i>Yes, I know</i>	21	19.1
	<i>No, I don't know</i>	89	80.9
If MA that integrated the management of BOZP and PO services were commonly available on the market, would you purchase them?	<i>Yes, I would purchase</i>	86	78.2
	<i>No, I would not purchase</i>	0	0.0
	<i>We have purchased</i>	9	8.2
	<i>I will decide later</i>	15	13.6

N – observed numerosness, N_R – relative observed numerosness in %, MA – mobile application.

Table 3 Comparison of respondents' answers to questions regarding the use of mobile applications for the management of BOZP and PO services (N = 110)

Chi-square goodness-of-fit test					
Questions	Categories	N	N _R	χ ²	p
Do you use MA to provide BOZP and PO services?	No	79	71.8%	20.945	<.001
	Yes	31	28.2%		
What is your attitude towards MA, the solutions which simplify the management of the fulfillment of obligations?	Negative	38	34.5%	10.509	<.001
	Positive	72	65.5%		
Do you know special MA that would integrate the management of BOZP and PO services?	No	21	19.1%	42.036	<.001
	Yes	89	80.9%		
If MA that integrate the management of BOZP and PO services were commonly available on the market, would you purchase them?*	Yes	95	86.4%	58.182	<.001
	Probably	15	13.6%		

N – observed numerosness, N_R – relative observed numerosness in %, χ² - chi-square goodness-of-fit test, p – level of statistical significance.

* Respondents had the option to choose the answer "no", but no one chose it.

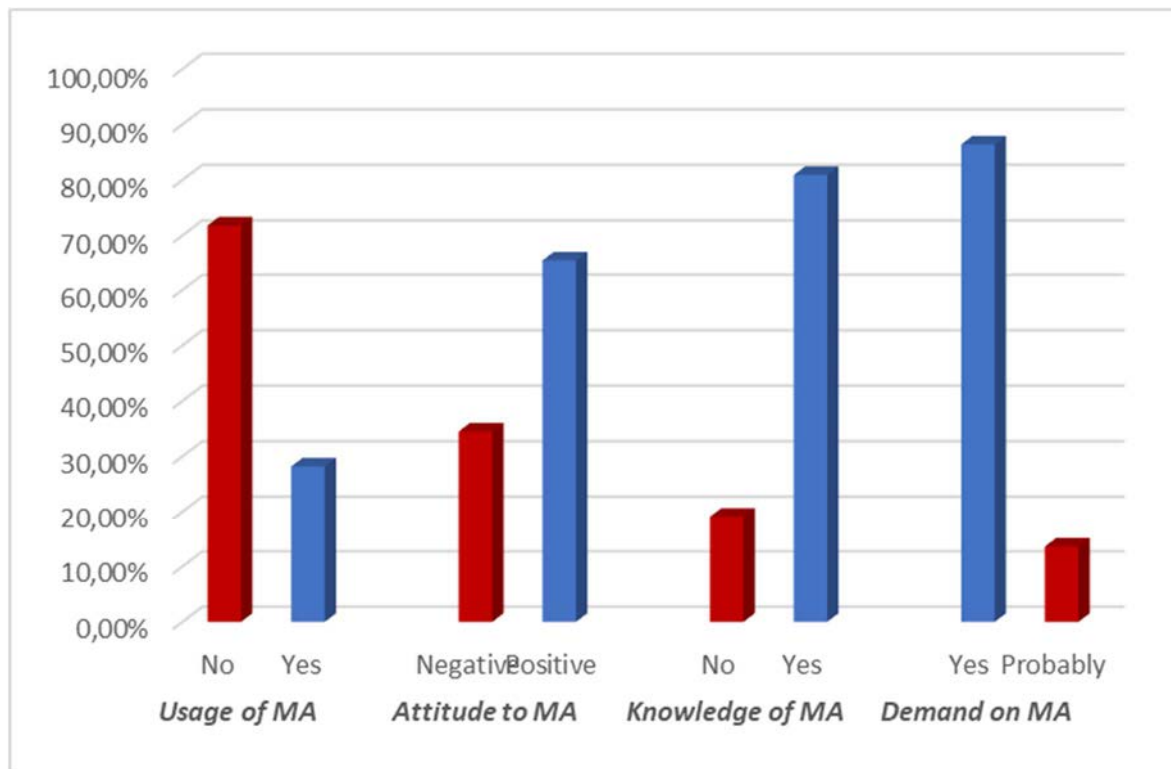


Figure 1 Comparison of respondents' answers to questions regarding the use of mobile applications for the management of BOZP and PO services (N = 110)

RH2: Micro, small and medium-sized enterprises prefer to the most significant extent the functionalities "records of initial and repeated training of BOZP and PO" and "BOZP checks and preventive fire inspections" in the framework of mobile applications for the management of BOZP and PO services.

We verified the assumption that micro, small and medium-sized enterprises prefer to the most significant extent the functionality "records of initial and repeated

training of BOZP and PO" and "BOZP checks and preventive fire inspections" in the framework of mobile applications for the management of BOZP and PO services using Friedman analysis of variance.

The results of the analysis showed that in the case of various functionalities of mobile applications integrating BOZP and PO services, there are statistically significant differences in terms of their preference by enterprise representatives, $\chi^2(5) = 307.309$, $p < .001$. Specifically, we

found that enterprise representatives significantly preferred the functionality "records of initial and repeated training of BOZP and PO" (MR = 1.32). The second most preferred was the functionality of "BOZP checks and preventive fire inspections" (MR = 2.35). From the point of view of preference, the following were the functionalities "management of reserved technical equipment, records and revisions" (MR = 3.85) and "specialised training of BOZP

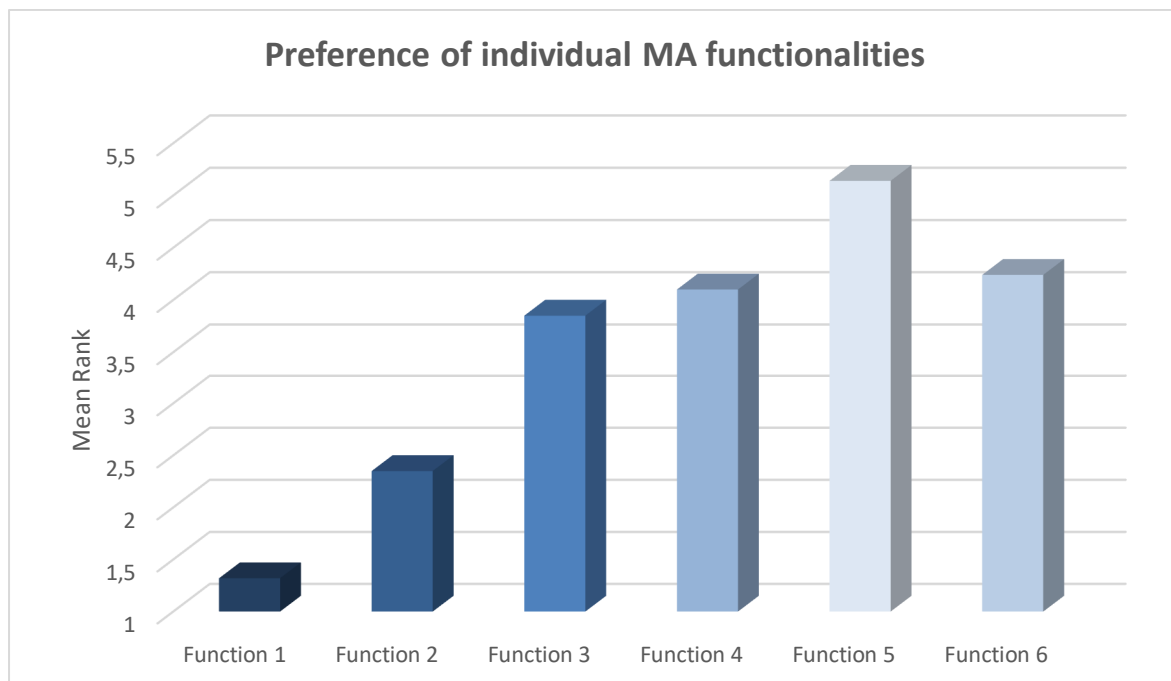
and PO" (MR = 4.10). On the contrary, enterprise representatives significantly least often preferred the functionality of "personal protective work equipment" (MR = 5.14) and "management of fire-technical equipment, records and controls" (MR = 4.24). The above findings supported our research hypothesis. The results are summarised in Table 4 and graphically represented in Figure 2.

Table 4 Comparison of preferences for individual functionalities that mobile applications that integrate BOZP and PO management would have (N = 110)

Interactional styles of teachers	Descriptive indicators				Friedman's analysis of variance		
	MR	AM	Mdn	SD	χ^2	df	p
<i>records of initial and repeated training of BOZP and PO</i>	1.32	1.32	1	0.877	307.309	5	<.001
<i>BOZP checks and preventive fire inspections</i>	2.35	2.35	2	0.698			
<i>Management of reserved technical equipment. records and revisions</i>	3.85	3.85	4	0.788			
<i>the specialised training of BOZP and PO</i>	4.10	4.10	4	0.938			
<i>personal protective work equipment</i>	5.14	5.14	5	1.104			
<i>Management of fire-technical equipment. records and controls</i>	4.24	4.24	5	1.953			

MR – mean rank, AM – arithmetic mean, Mdn – median, SD – standard deviation, χ^2 – Friedman analysis of variance, df – degrees of freedom, p – level of significance.

Respondents had to rank individual functionalities in order of priority, with 1 – the most important functionality and 6 – the least important functionality. A lower score thus represents a higher preference or importance.



Functionality 1 – records of initial and repeated training of BOZP and PO, Functionality 2 - BOZP checks and preventive fire inspections, Functionality 3 - management of reserved technical equipment, records and revisions, Functionality 4 –specialised training of BOZP and PO, Functionality 5 -personal protective work equipment, Functionality 6 - management of fire-technical equipment, records and controls.

Notice: MA = Preference of individual MA functionalities.

Figure 2 Comparison of preferences for individual functionalities that mobile applications that integrate BOZP and PO management would have (N = 110)

5 Conclusions

The findings in this article point to the possibilities of increasing the efficiency of logistical assurance of the fulfilment of obligations in the area of BOZP and PO using applications. The article points out the importance of protecting the life, health, and property of natural and legal persons, as well as the high difficulty of fulfilling legislative requirements. Based on our research and statistical evaluation, we found that the market lacks an offer of integrated mobile applications for which there is a potential demand from micro, small and medium-sized enterprises. Based on the evaluated survey, it can be concluded that enterprises have a positive attitude towards mobile applications, but do not use them due to their unavailability. We can also support the stated statement on the theoretical part, on the basis of which we found a limited offer of software solutions in the addressed area.

Currently, mobile applications are popular with the public as well as with enterprises, as they streamline the process of fulfilling complex and extensive obligations. The search for solutions can be in logistics startups, which mainly develop applications and try to increase customer convenience, thereby improving people's quality of life [23] and thus increasing customer satisfaction in services. The stated findings and research evaluations create space for innovative creators of mobile applications, who have opportunities to develop and innovate their entrepreneurial activities. Innovative solutions are aimed at reducing the number of occupational fatalities, common injuries, and property damage to natural and legal persons. For enterprises, the use of these mobile applications means saving time, more efficient and innovative fulfilment of mandatory legislative obligations. Mobile applications will enable easy communication between enterprises and enterprises that provide BOZP and PO services. At the same time, they create space for more effective training and specialised periodical training.

The findings of the article also point to the priority order of the functionalities of the individual areas of BOZP and PO. The given order points to a research gap that can be the subject of further scientific research in the area of logistics of BOZP and PO services. The reasons why individual functionalities are prioritised, others less so, may point to problems in security logistics, which can be addressed by further scientific research. Therefore, we recommend that scientific research be focused on individual functional areas and the problems that arise when securing them.

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Combination of FTA and FMEA methods to improve efficiency in the manufacturing company

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Abstract: Toroidal is an inductor with an O-ring core. In 2021 there was an increase in the percentage of toroidal disability, namely the highest percentage of disability at 2.78%, while in 2020 the highest percentage of disability was only 1.33%. Therefore, companies need to make improvements to the quality of their products to prevent a continuous rise in the percentage of defects over time. This study aims to propose an enhancement to reduce/prevent defects in toroidal inductor products. The method used is the Fault Tree Analysis (FTA) and Failure Mode and Effect Analysis (FMEA). The FMEA method is utilized to reduce flaws that occur by considering the value of the risk priority number (RPN). The FTA method is used to identify possible defects by applying analysis of the fault tree description. The results of this study are that improvements should be focused on the failure mode of the wound wire because it gets the highest RPN value of 216 with the cause being less focused workers, while the lowest RPN value is on the red pin failure mode of 56 with the cause of no sandpaper changing schedule. From the results of the study, several suggestions for improvements were made in the form of increasing supervision for workers, increasing rest periods, conducting training, installing display limits for stripping, repairing stripping machines, replacing vise, repairing worktables, and making a schedule for sandpaper replacement prevents the defect. Companies must make improvements to human flows and ensure tools and materials are in optimal condition.

1 Introduction

The electronics industry is one type of industry that consistently has the largest contribution to economic growth in Indonesia in 2019 [1-3]. In its development, the electronics industry has become a big consideration for business actors in the field of electronic equipment spare parts to expand their scope and contribute to its improvement. CV. CKM is a company that produces spare parts for electronic equipment. Electronic equipment produced by CV. CKM is a toroidal inductor.

This toroidal inductor itself is an electronic equipment spare part that functions as a store of energy or electric current with a larger inductance and a size that tends to be smaller than other types of inductors. The toroidal core is usually circular so that the magnetic field is closed and relatively little or even does not induct other components in the vicinity.

Along with the development of the electronics industry, in 2021 there was a surge in demand for toroidal products at CV. CKM causes the manufacturing company to produce more products than usual. The more companies produce products, it turns out that the more defective products are produced by the company. In 2021 the highest percentage of defective products produced by the company

was 2.78%, this is the highest number for the percentage of defects in the company compared to previous years which was only in the range of 1%.

The existence of defective products certainly results in waste for the company, both in terms of materials and also in terms of the disposal of the defective product [4]. Although some defective products can be reworked, the presence of rework defects is also very detrimental because the company will need additional costs to reprocess the reworked defective products [5].

In addition to the losses described previously, defective products are very dangerous if they escape the quality control section and are used by the customer. Because considering its function as an inductor, if there is a mismatch such as a scratch on the wire (wire wound) it will result in an induction field or an open magnetic field so that it can induce other components that are around, and if there is a lack of stripping defects it can cause a red pin due to If the enamel wire is not peeled properly, it will result in not flowing or not optimally flowing the magnetic field by the toroidal.

Based on these problems, the company must take corrective steps to reduce or even eliminate defective toroidal inductors. So, the objectives of this study are:

a. Recognize factors causing defects in toroidal

products in CV. CKM.

- b. Make suggestions for improvement based on the priority of repairs to reduce defective products.

2 Literature review

This study was carried out using methods of Fault Tree Analysis (FTA) and Failure Mode and Effect Analysis (FMEA). Failure Mode and Effect Analysis (FMEA) is a procedure to describe various kinds of potential failures in a structure and then analyze them to determine their effect on the system so that they can be classified based on their severity [6]. Meanwhile, Fault Tree Analysis (FTA) is an analysis technique of failure conducted from top to down that aims to find the cause or a combination of causes that may cause unsafe conditions to a lower or basic failure rate. This makes FTAs an excellent complement to FMEA [7]. The FTA used in this study is to find out factors causing failures in the FMEA manufacturing process, namely at the phase of determining the cause of failure. FMEA is an effective and formidable analytical tool that is greatly used to check modes of failure and terminate the possibility of failure [8].

2.1 Fault Tree Analysis (FTA)

FTA or Fault Tree Analysis (FTA) is an approach applied from top to down that is used to analyze failures that start with potentially unwanted events and then determine the causes of how these events could occur [9]. FTA is also an alternative to identify the possibility of failure by using a diagram of a fault tree as reasoning that signifies the relationship between a failure and the cause of the failure [7]. This logic gate will later help in building a more detailed schema of the relationship between events that can affect its quality [10]. The logic gates that are usually used in the FTA manufacturing process consist of AND gates which are used when all input events occur and OR gates are used when one of the input events occurs [11]. The event symbols that are often used for making FTAs are the Top Event symbol which symbolizes the main event which is always placed at the peak of the tree of fault, and also the event symbol which describes an intermediate failure event that can be used anywhere except at the basic level of the fault tree and the basic event symbol which symbolizes the lowest failure event or base on the fault tree [12]. FTA differs from diagrams of a block of reliability and has a wider scope than diagrams of reliability block [13,14].

2.2 Failure Mode and Effect Analysis (FMEA)

Failure Mode and Effect Analysis (FMEA) is a structured way that can identify and prevent as many failures as possible [15-17]. The method of FMEA is used to set, recognize, and abolish failures or potential failures before the product reaches the customer [18].

FMEA has a purpose to perform any action to abolish and degrade the occurrence of failures based on activities that have the highest potential [19]. FMEA can assist in selecting critical parameters of each process [20]. In

addition, FMEA can also document actions regarding the risk of failure that can be used by companies for continuous improvement. The steps taken in making FMEA documentation are [21]:

- a. Determine the components of the production system or process to be analyzed.
- b. Identify the function of the system or production process.
- c. Identify the mode of failure.
- d. Determine the influence of the failures of each process.
- e. Specify the cause of failure.
- f. Specify value of severity.
- g. Specify occurrence value.
- h. Specify value of detection.
- i. Calculating the Risk Priority Number (RPN) value is carried out to determine a failure that becomes a priority from each mode of failure using the following formula: $RPN = S \times O \times N$ (1).
- j. Recommend corrective actions of the highest priority.

FMEA is usually used to evaluate parameters such as occurrence, severity, and also detection in determining the Risk Priority Number (RPN) [22]. The severity value (S) determination or the severity value of this failure starts with a scale of 1 as the smallest scale with low consequences to a scale of 10 with the highest consequences, so that the severity scale assessment is based on how serious the effects of a failure are [23]. While the assessment of occurrence or probability level usually refers to the failure mode or several failures on a scale of 1 to 10, where 1 becomes the lowest possibility of failures, while 10 turns out to be the highest one [22]. As for the detection value based on the possibility of failure to be detected which is given a value scale of 1 to the most difficult or even undetectable with a scale of 10, the determination of this detection scale refers to the cause of the failure with the current controls [23]. FMEA method is utilized to determine which risks have the greatest concern and action is needed to prevent problems before they arise [24]. The smallest RPN value is better than the largest because the largest value indicates the severity of the risk of failure.

3 Methods

The use of FMEA and FTA methods can be merged for analysis of failures so that the advantages of each of these methods can be obtained, by using the FMEA and FTA approaches separately or by using a combined approach between the two [22]. FTA describes the causes of errors in more detail by pointing to the topmost event which is not expected to occur, while FMEA provides an overview of where this error occurs and what effects will be caused by the topmost event error [25].

Compared to the use of FTA and FMEA alone, researchers prefer to utilize a merger of FMEA and FTA because it is considered to have an advantage in detecting

errors [26]. In addition, FTA is considered only able to analyze the causes of failure in detail without considering the criticality and risks that exist, so FMEA is needed as a complement to FTA because FMEA can assess criticality and risk [7]. The combination of these two methods is recommended to be used for production processes that are carried out repeatedly because it provides a clear view of analysis, collecting mechanism of similar data, and the relations between error modes and failures [26].

4 Result and discussion

Problem-solving is used using the FTA and FMEA methods. The use of FTA in this research is a complement

to the process of making FMEA. At the stage of making FMEA, namely in determining factors causing failures, the FTA method is utilized to determine factors causing failure to the basic cause.

4.1 Identify Failure Mode

Before identifying the cause of failure, the initial step in building an FMEA is to identify the failure mode. recognition of modes of failure or types of defects will be described using a diagram called Pareto to specify the dominant type of flaw that causes disabilities. The Pareto diagram for each type of disability can be seen in Figure 1.

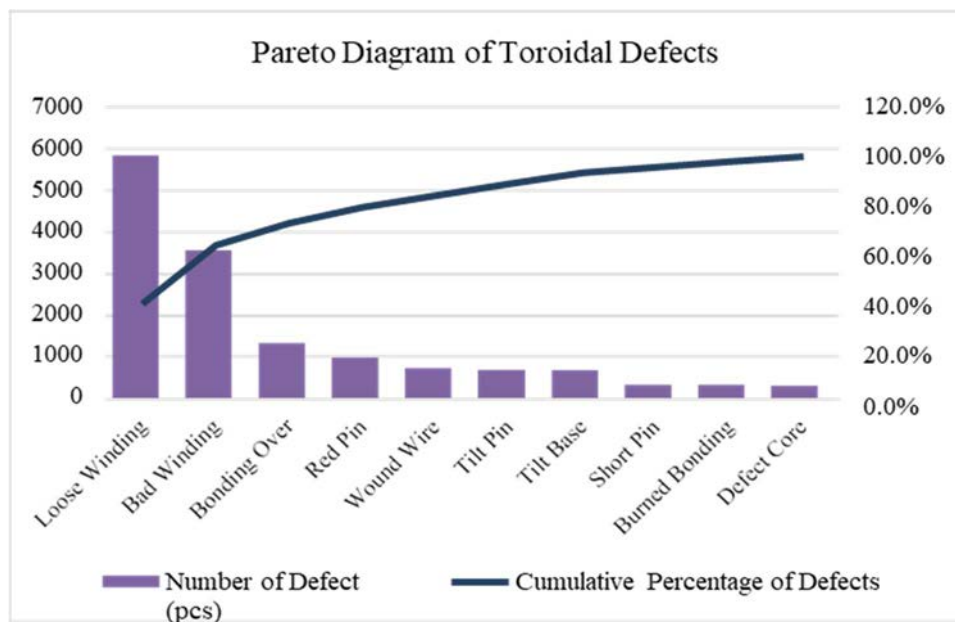


Figure 1 Pareto diagram types of Toroidal Inductor Product Defects

Under the Pareto 80:20 principle, the failure mode will then be identified as the cause of the failure, namely loose winding, bad winding, bonding over, red pins, and wound wires which are included in the 80% cumulative percentage of defects. So, these five types of defects or failure modes must be corrected so that defective products can be reduced.

4.2 Identify Causes of Failure

To build an FMEA, you must first identify the causes of failure. The failure to be analyzed further is following

the dominant disability on the diagram of Pareto, namely the top five kinds of defects which are included in 80% of cumulative defects. Identification of the causes of failure exist at the phase of making this FMEA is done employing FTA. The use of FTA for the cause of this failure because FTA can describe the causes of failure based on the top events to the most basic causes that cause failure or defects. Identification of factors causing failure using the fault tree analysis is provided in Figure 2 – Figure 6.

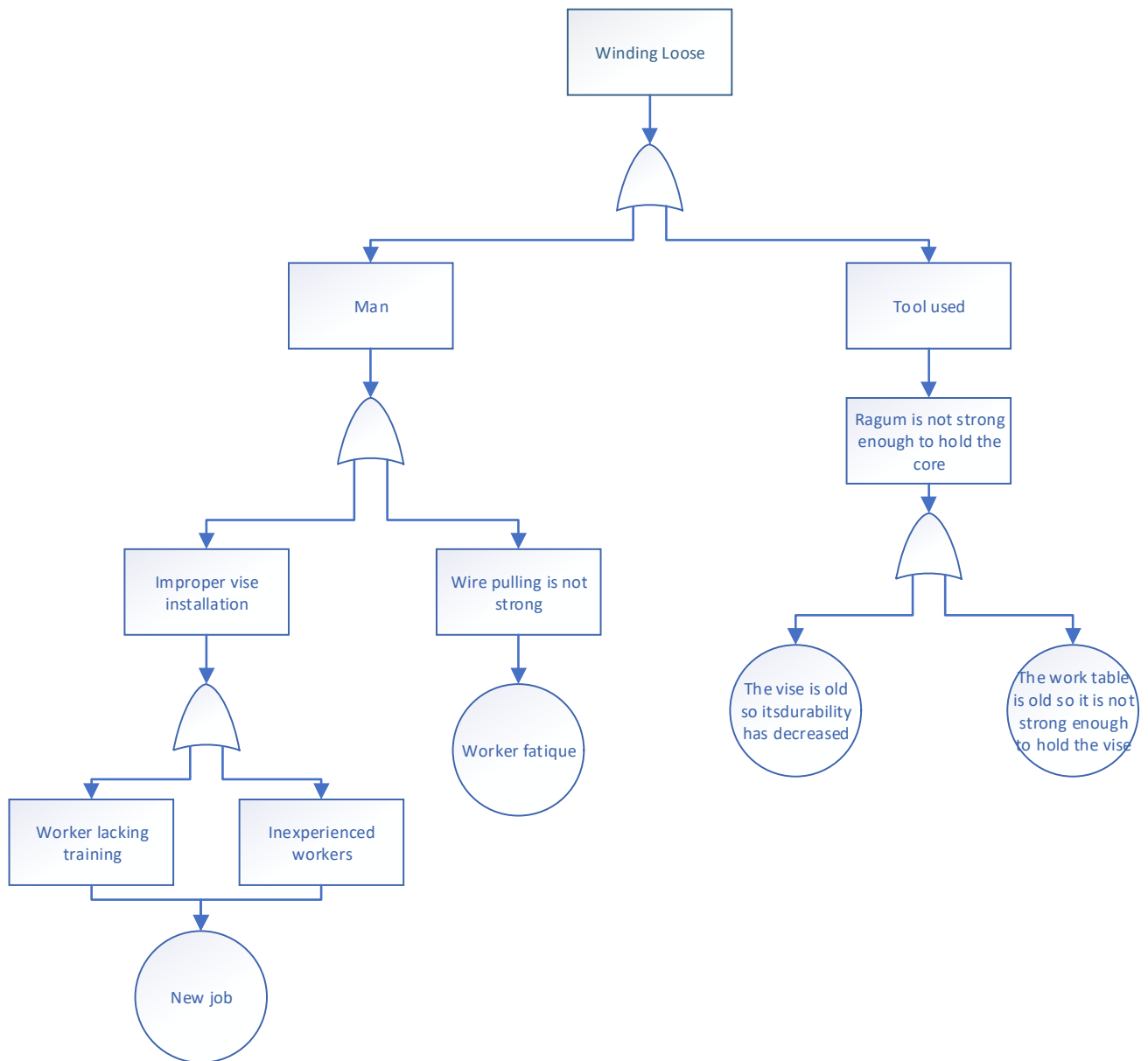


Figure 2 FTA Winding Loose

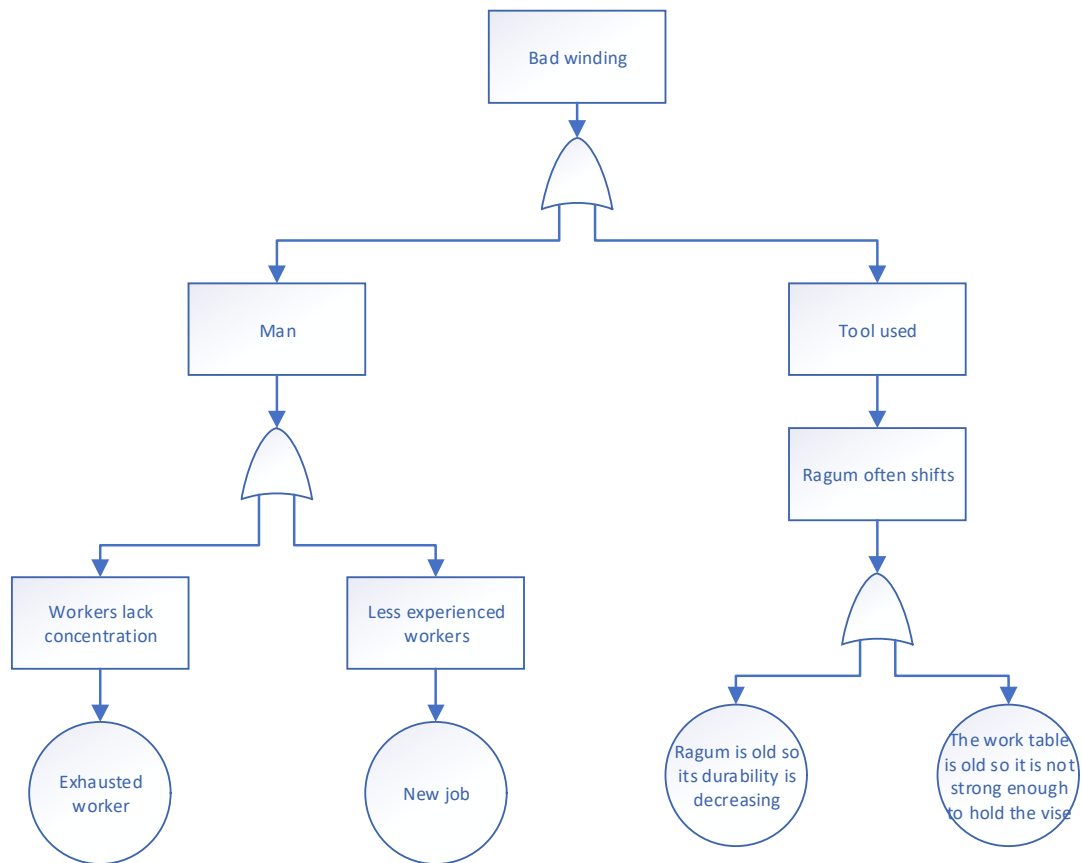


Figure 3 FTA Winding Bad

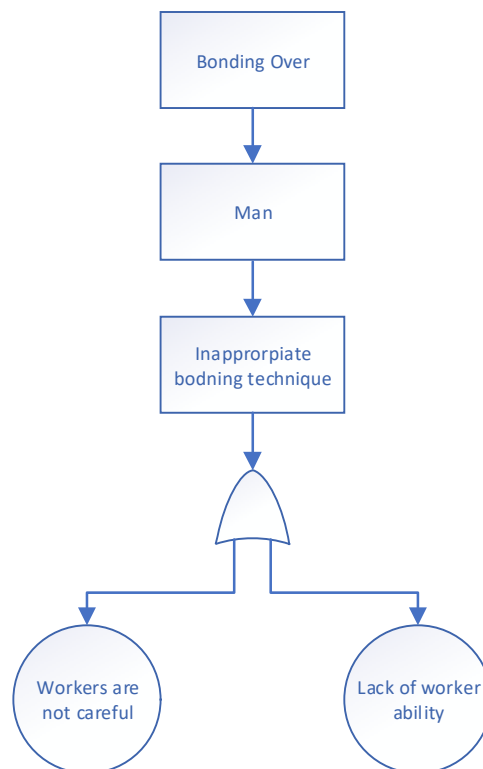


Figure 4 FTA Bonding Over

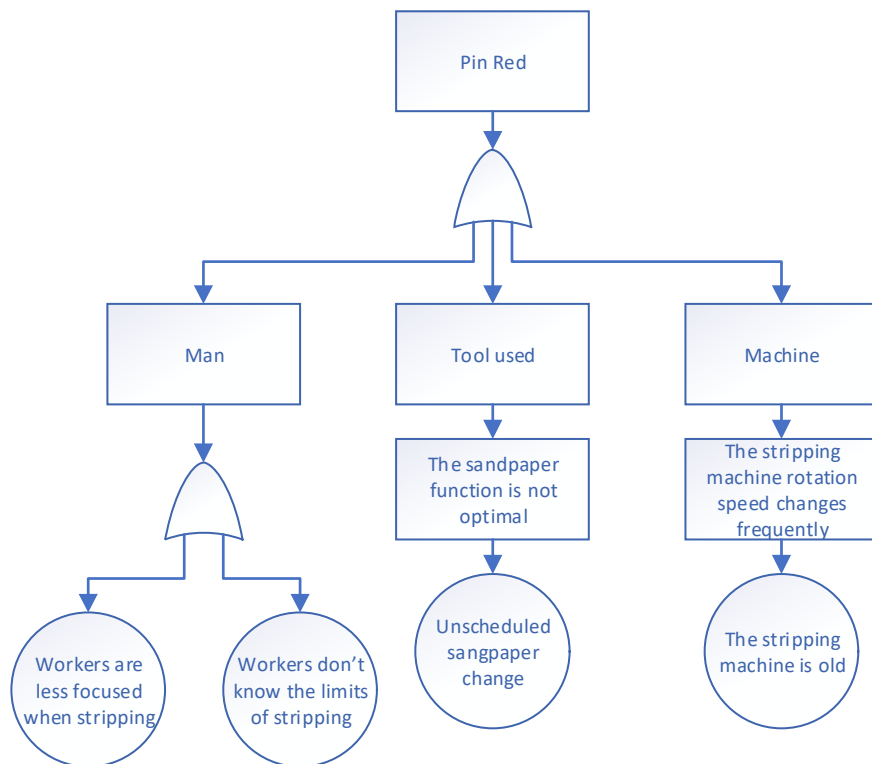


Figure 5 FTA Pin Red

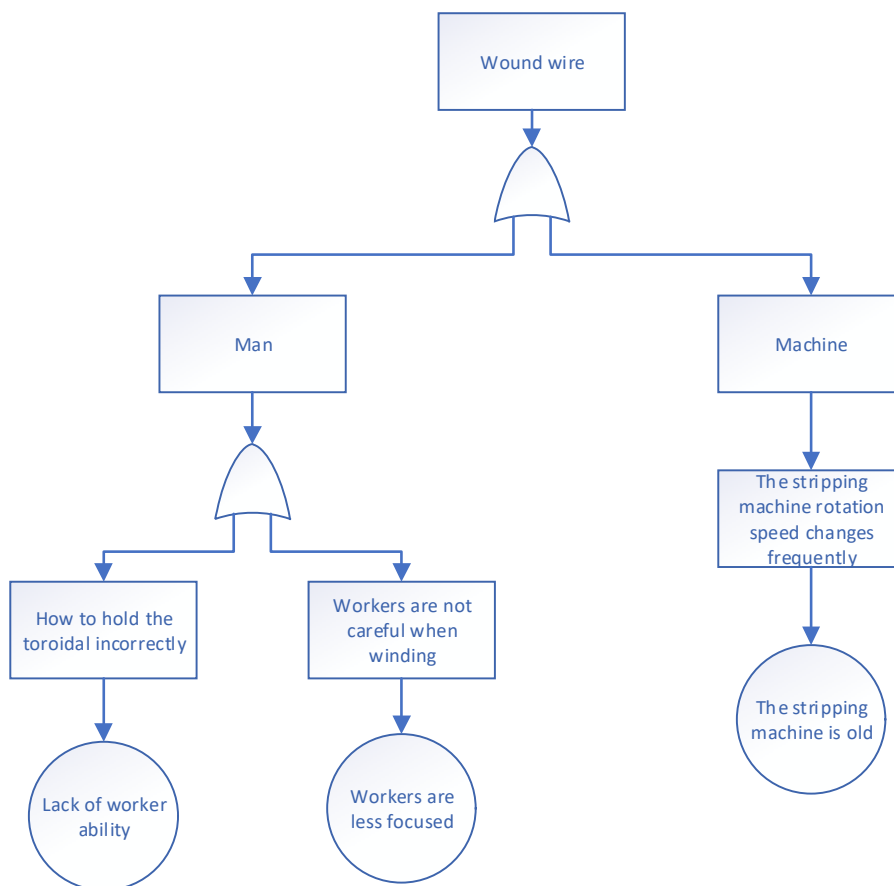


Figure 6 FTA Wire Wound

4.3 Calculation of RPN Value in FMEA

After knowing the mode of failure and its causes that occurs in toroidal inductor product, the subsequent step is to rate the scale of severity, detection, and occurrence. Determination of the rating scale of the level of seriousness (severity) is used to find out how serious the consequences will be if the disability occurs. After rating the scale of severity, the next step is to rate the scale of the value of the probability of failure (occurrence). Determination of this occurrence value scale is done to find out how often the defect occurs by looking at the existing failure modes. This assessment is carried out objectively based on the data available in the mode of failure. The phase of rating the scale of value of detection level is carried out to predict

how often defects occur. This assessment is carried out through discussions with the company, namely by the head of the production department. This assessment is based on the potential causes obtained using the FTA method and adapted to the control processes carried out by the company at this time.

After performing the severity rating, occurrence rating, and rating of detection, calculating the value of RPN (Risk Priority Number) becomes the subsequent step to be taken. The RPN value calculation is conducted to set the priority of repairs according to the peak value. The largest values of RPN are sorted to the smallest value so that it can be seen what improvements must be made first. The FMEA documentation outcomes are shown in Table 1 which presents the top RPN value as a reference for enhancement.

Table 1 FMEA documentation results

Function/ Process	Potential Failure Mode	Potential Failures Effect	Potential Causes	Current Control	Severity (S)	Occurrence (O)	Detection (D)	RPN	Rank
Winding	Winding Loose	The toroidal function is not optimal	New job	No regular training schedule	7	5	5	175	4
			Worker fatigue	Supervision from the head of the production			6	210	2
			Ragum is old	Ragum check periodically			3	105	10
			The desk is old	Checking the workbench regularly			2	70	14
	Bad Winding	The product shape is not up to standard	Worker fatigue	Supervision from the head of the production	6	5	6	180	3
			New job	No regular training schedule			5	150	6
			Ragum is old	Ragum check periodically			3	90	12
			The desk is old	Checking the workbench regularly			2	60	15
Bonding	Bonding Over	Causing a glob of glue on the toroid	Workers are not careful	Supervision from the head of the production	5	4	6	120	8
			Lack of worker ability	No regular training schedule			5	100	11
Stripping	Red Pin	The toroidal function is not optimal	Workers are less focused when stripping	Supervision from the head of the production	7	4	6	168	5
			Workers don't know the limits of stripping	No regular training schedule			5	140	7
			Unscheduled sandpaper change	Inspection by workers			2	56	16
			The stripping machine is old	Regular machine checks and repairs			3	84	13
Winding, Stripping	Wound Wire	Toroidal can induce other components around it	Lack of worker ability	No regular training schedule	9	4	5	180	3
			Workers are less focused	Supervision from the head of the production			6	216	1
			The stripping machine is old	Regular machine checks and repairs			3	108	9

5 Result analysis

This study combines the FTA and FMEA methods to reduce defects in toroidal products in the company. FTA is used to determine the cause of defects in each failure mode.

While FMEA is used to appraise the risk of each mode of failure so that improvements can be prioritized.

The causes of defects in toroidal products are dominated by humans/workers, machines, and tools used during the production process. These three factors are the

main factors causing the failure. While the results from FMEA are the main priority for repairing the wound wire of mode of failure with a value of RPN 216 with the cause of workers or humans being less focused. The lowest RPN value is in the red pin mode of failure with a value of 56 which is caused by the absence of a sandpaper replacement schedule. Then a proposed improvement is made for every mode of failure according to the priority of improvement from the highest to the lowest RPN value.

Some suggestions for enhancement that can be provided are increasing supervision from the head of production for employees, providing additional rest time for workers, conducting training, installing display limits for correct stripping, repairing stripping machines, replacing vise, making repairs to worktables and sandpaper replacement schedule. This improvement proposal was made to increase efficiency in the production of toroidal inductors.

After the proposed improvement was implemented by the company, the percentage of defects fell to 1.25%. So that the improvements made are considered sufficient to increase efficiency in the production of toroidal inductors, although the implementation of this proposed improvement cannot be done entirely. The implementation of the new improvements made by the company is in the form of increasing supervision, providing rest periods, installing stripping limit displays, repairing worktables, and regular sandpaper replacement schedules.

6 Conclusions

According to the outcomes of research that has been conducted, the researchers draw the conclusion that the identification results of FTA (Fault Tree Analysis) are known that the factors that cause defects in toroidal products include humans, machines, and tools used. According to the outcomes of RPN values obtained in the process of making FMEA, the suggestions given include:

- a. Increase the supervision of the head of the production.
- b. Provide additional rest time for workers.
- c. Conduct regular training.
- d. Installing border display doing stripping.
- e. Stripping machine repair.
- f. Perform a vise replacement.
- g. Workbench repair.
- h. Make a sandpaper change schedule.

Companies must make improvements to human flows and ensure tools and materials are in optimal condition. Therefore, the logistics factor of the material must be given more attention by the manufacturing company

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