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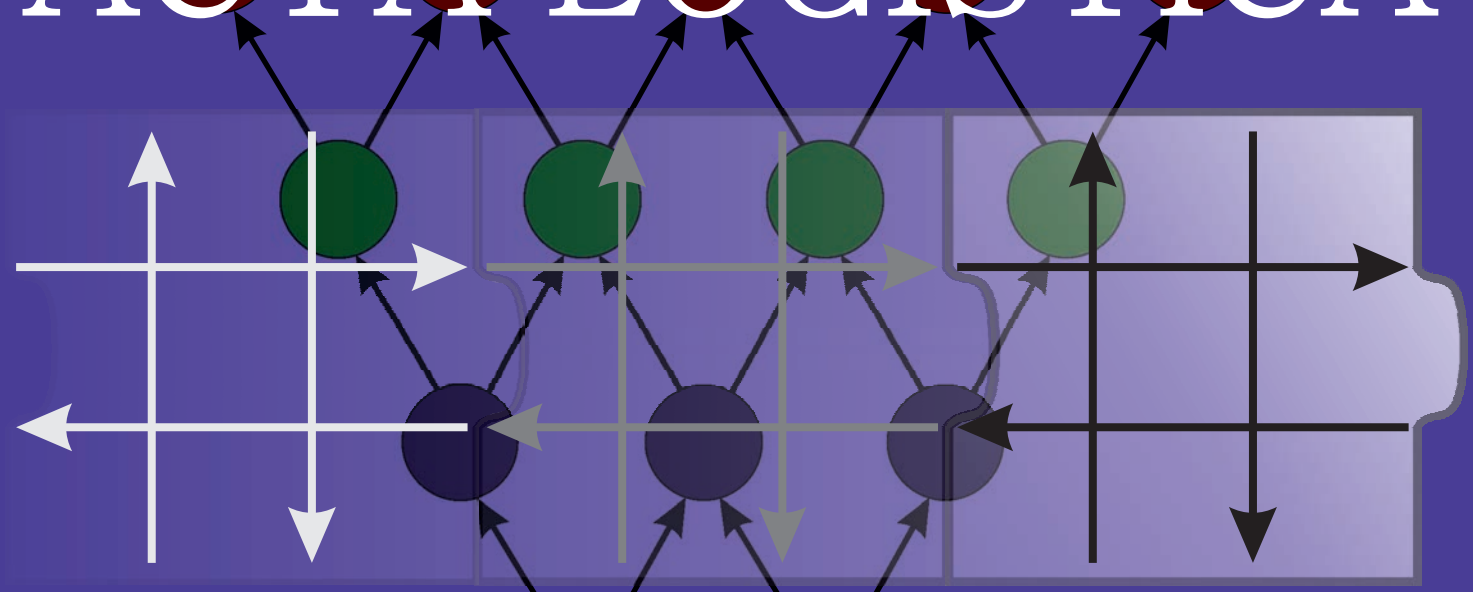

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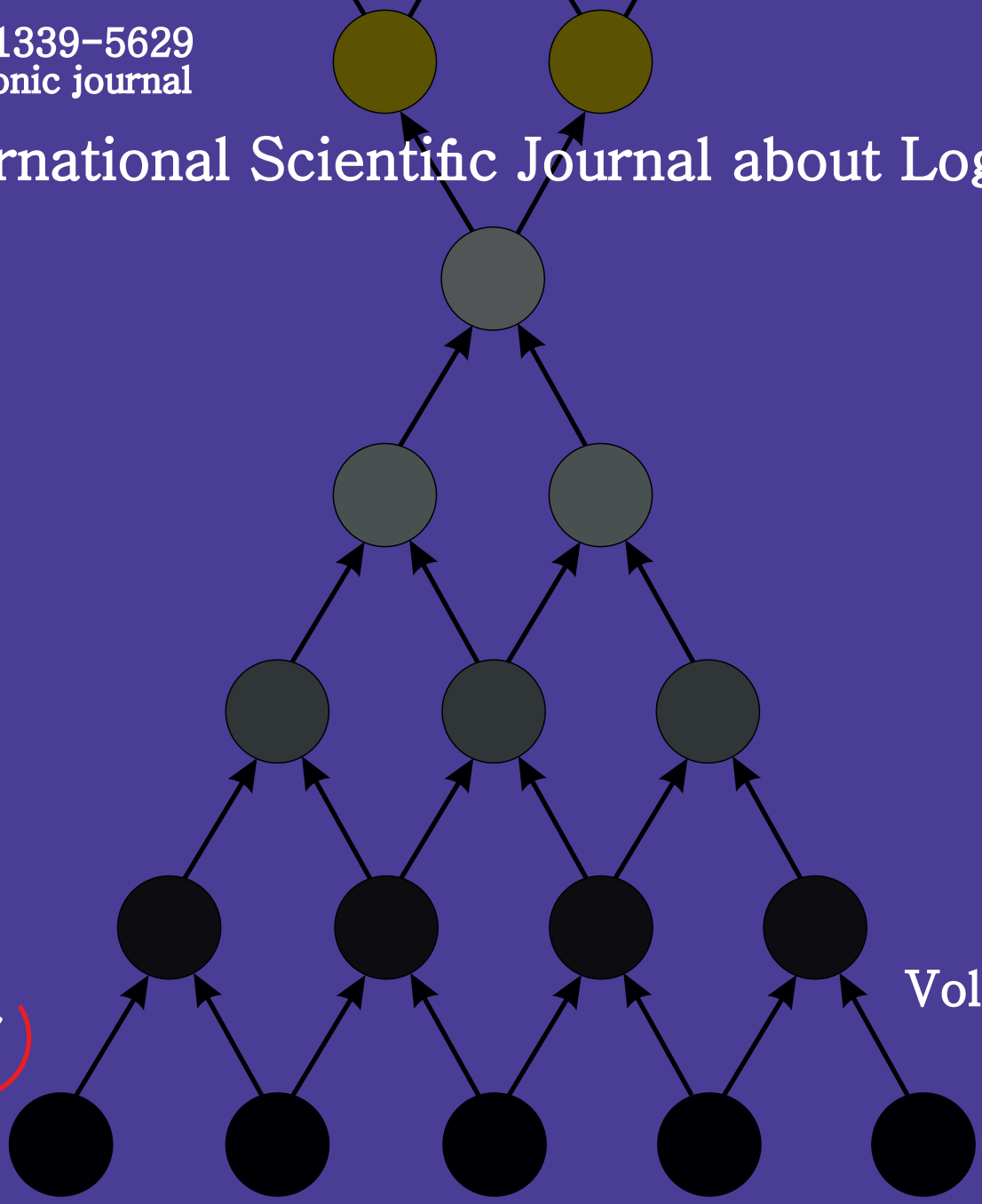

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Diego A. Tamayo, Javier Arturo Orjuela-Castro, Milton M. Herrera

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Assessing the Bullwhip effect in supply chain: trends, gaps, and overlaps

Diego A. Tamayo
Universidad Distrital Francisco José de Caldas, Cra 7 #40 -53, Localidad de Chapinero, Bogotá, Colombia, datamayov@correo.udistrital.edu.co (corresponding author)
Javier Arturo Orjuela-Castro
Universidad Distrital Francisco José de Caldas, Cra 7 #40 -53, Localidad de Chapinero, Bogotá, Colombia, jorjuela@udistrital.edu.co
Milton M. Herrera
Universidad Militar Nueva Granada, Cra. 11 # 101-80, 111071 Bogotá, Colombia, milton.herrera@unimilitar.edu.co

Keywords: Bullwhip effect, operational, behavioral, disruptions.
Abstract: Due to operational and behavioral factors, the Bullwhip effect (BWE) arises with variations in the logistics flow, yielding uncertainty and disturbances along the supply chain (SC). Previous studies have discussed isolated approaches, underestimating the influence of behavioral aspects over operational ones, and multi-factor analysis, which helps to measure and diminish the BWE. This study systematically assesses the bodies of knowledge to identify new trends, emphasizing gaps and overlaps to underly behavioral-operational links and multi-factor scenarios through a unified frame of reference built during the paper review. The results from this research spot new BWE trends like COVID and closed-loop supply chain (CLSC) driven by disruption and return flows; the influence of behavioral causes over pricing, returning flows, production capacity, and batching; the combination of multi-factor topics like pricing, production capacity, synchronization, and order batching. This overview contributes to understanding new trends and connections in the issues, highlighting logistic challenges and opportunities to explore future studies with a broader scope. It also elucidates the BWE causes and how to handle them, which could assist in comprehending its effects and advantages on the technical elements of logistics.

1 Introduction

Supply chain (SC) is a complex system with actors making multiple decisions influenced by behaviors, feedback information, non-linearity, delays, deviations, and uncertainty to satisfy the demand of retailers and customers [1,2]. Lack of synchronization between SC members yields demand variations, batch size oscillations [3], and thus BWE, where SC actors mitigate fluctuations and resource shortages through a misguided decision-making process by reacting and changing the capacity to meet peak demands. This effect increases safety stock level investments, transportation costs, unstable planning, unmet service acceptance levels (SAL), running out of products, and revenue loss, affecting the company profit between 10%-30 % and the inventory balance, increasing holding and shortage costs [4-6].

The behavioral BWE describes stakeholders' interventions and decision-making processes reflected in operational aspects [7]. Although there has been an increasing interest in studying human behavioral factors associated with the BWE, most of this analysis is still at the individual level. It is necessary to extrapolate these factors to a cultural and societal level, including more case studies that replicate a real-world business scenario with complexity instead of the beer game simulation [8].

Previous studies addressed variables that compound the BWE effects from different viewpoints to describe, measure, and reduce the impact on the SC [9], highlighting the need to close the gap between theoretical definitions and complex systems. Analytical, empirical, and experimental methodologies have been implemented in different components related to demand, replenishment policy, and coordination to rethink the SC role, structure, product type, price strategy, competition, and sustainability. This trend to enhance the scope of the BWE analysis has led to include econometric variables like costs and price to improve the outcome [10] and influence demand through communication strategies to align consumers with the level of the stocks to increase or decrease orders. Furthermore, multiple components have explored new pricing models like marketing techniques, technologies, inventory policies, forecasting methods, and multi-echelon SC [11,12]. Information exchange and vendor-managed replenishment schemas to reduce the BWE have evolved into synchronized SC. However, integration complexity, lead time, lack of trust, and transferred information delays are challenges to overcome [13,14].

Including a multi-factor approach to the BWE is an overdue opportunity to explore topic combinations to analyze closer-to-reality studies with multivariable causes; future studies may research complex systems, pricing strategies, service chains, and competitiveness factors [10]. Despite previous studies addressing bodies of knowledge, trends, assessing the status of repetitive topics, mitigation strategies, and behavioral-operational factors [15-17], this

paper identifies overlapping issues, gaps, synergies, future research, updating existing taxonomy, and combining frameworks to relate BWE causes. This study also shows strategies for SC decision-makers to identify and mitigate the BWE.

This research guides answering the question: How can the BWE issues be synthesized by clustering topics to illustrate existing links in the literature to identify gaps, trends, and future works? This paper builds a holistic view to contributing new insights, point likenesses, and BWE mitigation benefits.

This article is structured as follows: the methodology used to find the clustered topics and trends about BWE supply chains from the existing literature is presented in Section 2. Using the frameworks proposed by Bhattacharya et al. [15], Geary et al. [16], and Wang et al. [10] during the refinement phase addressed in Section 3, the problem, solution, and future research are extracted to identify trends, gaps, and overlaps. Section 4 depicts a visual analysis explaining overlapped operational and behavioral studies and the connection between causes, mitigation strategies, clustered topics, trends, and future research. Finally, the conclusions and future works are reported in Section 5.

2 Methodology

This paper presents a systematic literature review on BWE based on the methodology developed by Hosseini, Dmitry, and Dolgui [18]. The iterative process applies different criteria to filter pertinent contributions aligned with the goals of this study, carry out the analysis, and categorize the results, as illustrated in (Figure 1). The following sections present more detail on the methodology applied.

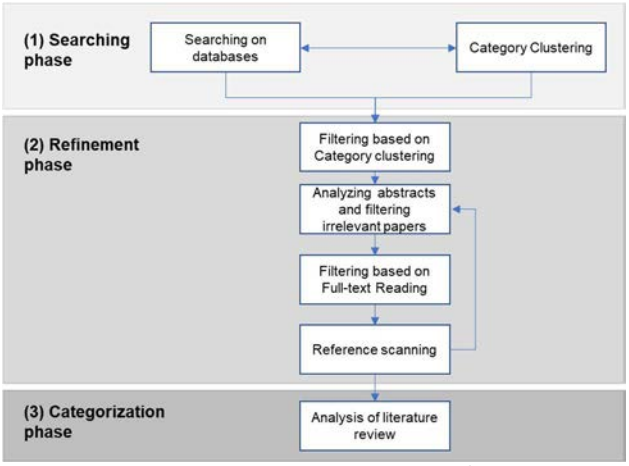

Figure 1 Literature-review methodology flow chart

2.1 Searching phase

The Web of Science and Scopus citation databases were used to build an overview of the topics, applying a search equation. TITLE-ABS-KEY("bullwhip effect") AND (EXCLUDE (SUBJAREA, "SOCI") OR EXCLUDE (SUBJAREA, "MATE") OR EXCLUDE (SUBJAREA, "ENVI") OR EXCLUDE (SUBJAREA, "PHYS") OR EXCLUDE (SUBJAREA, "MULT") OR EXCLUDE (SUBJAREA, "ENER") OR EXCLUDE (SUBJAREA, "CENG") OR EXCLUDE (SUBJAREA, "MEDI") OR EXCLUDE (SUBJAREA, "CHEM") OR EXCLUDE (SUBJAREA, "EART") OR EXCLUDE (SUBJAREA, "ARTS") OR EXCLUDE (SUBJAREA, "AGRI") OR EXCLUDE (SUBJAREA, "PSYC") OR EXCLUDE (SUBJAREA, "BIOC") OR EXCLUDE (SUBJAREA, "HEAL") OR EXCLUDE (SUBJAREA, "IMMU") OR EXCLUDE (SUBJAREA, "PHAR")).

The initial abroad exploration includes all the search results related to the "Bullwhip Effect" keyword, excluding non-English articles, and areas like Physics and Chemistry to zoom in on areas like Management, Operation Research, Logistics, and Economy. Secondly, both sources of information are joint, excluding duplicates to select 1,522 papers.

Category clustering: A clustering algorithm is applied to have a high-level view of relevant terms linked to the BWE studies using VOSviewer. This software extracts information from the title and abstracts to match and group topics. The full counting method calculates occurrences of keywords in the documents. The initial result was 20,813 terms, applying a minimum of 10 occurrences refines to 1,083 - the relevance score selected is 60%, equivalent to 650 terms. Finally, the list is cleaned-up to remove irrelevant terms to obtain 305 clustered topics.

Network visualization: The clustered topics network built (Figure 2a) explains the recurrency and links between the terms divided by colors. There are nine clusters: first [red], 63 items, agglomerates inventory, ordering, synchronization, reverse logistics, and distribution processes. The second [green], 47 items, combine technology, communication, and optimization. Third [blue], 42 items, brackets demand, pricing, and the market. Fourth [yellow], 40 items, links demand, costs, and stocks. Fifth [purple], 39 items, connects the beer game, supply chain structure, and simulation. Sixth [sky blue], 24 items, groups behavior, inventory information, and knowledge. Seventh [orange], 22 items, groups algorithm, vendor, and market. Eighth [brown], 16 items, associates closed-loop supply chain, control strategy, and inventory variance. Ninth [pink], 16 items, correlates COVID, supply chain risk, and inventory stock-out.

Overlay Visualisation: The clustered topics timeline (Figure 2b) exemplified when the BWE issues appeared, explaining it through the intensity of the purple and yellow colors. Since the first decade of the 2000s, terms like VMI (vendor-managed inventory), inventory policy, demand process, forecasting method, and beer game have been present, while new topics like COVID, price, disruption,

Big Data, closed supply chain, information transparency, resilience, supply agility, and market share emerged since 2016.

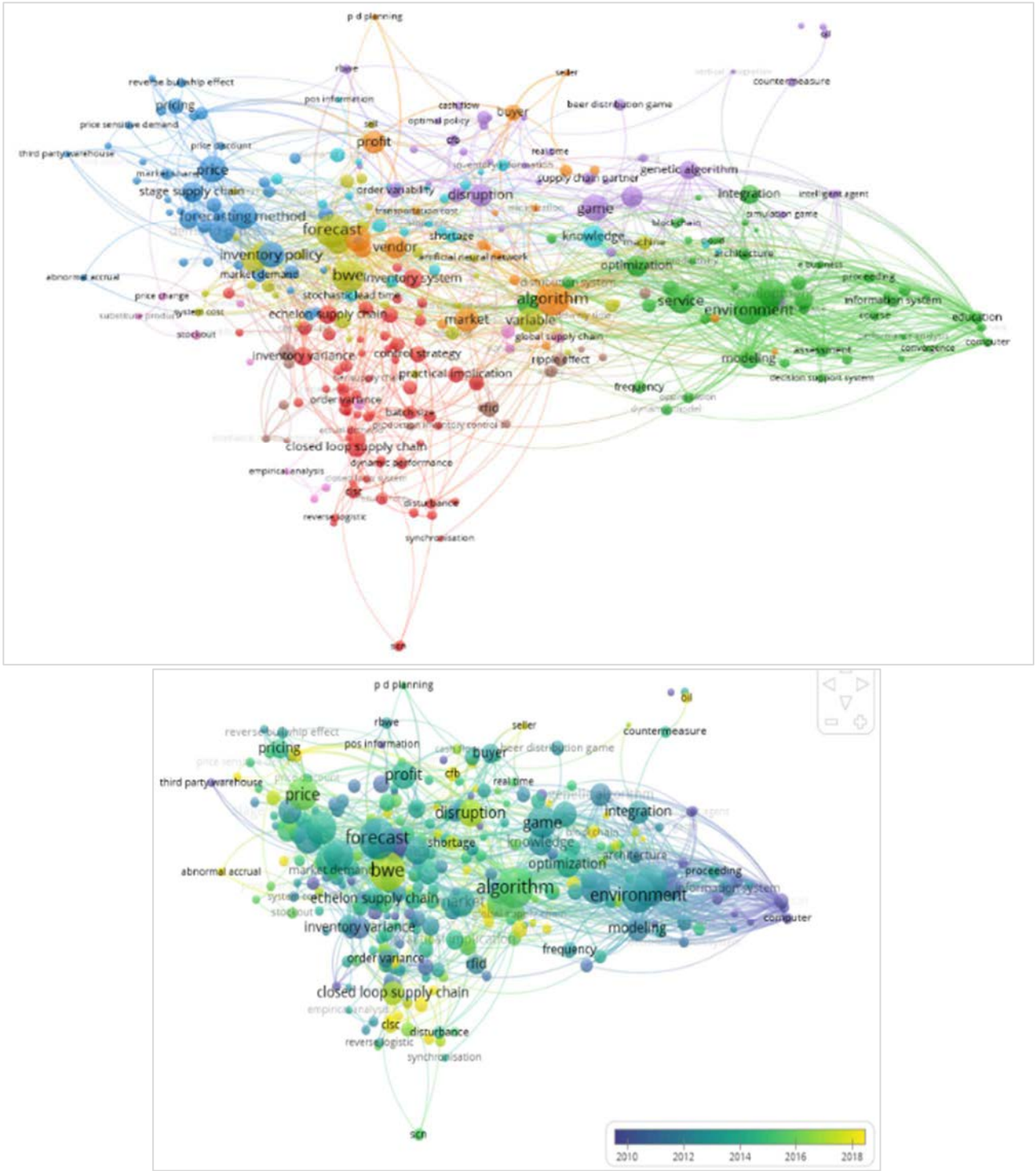

Figure 2 Category clustering timeline

2.2 Refinement phase

Refining the articles aims to understand how BWE issue has evolved, detecting recent trend topics and prominent contributing authors to concentrate on insightful research. The iterative process includes an abstract analysis, full-text reading, and reference scanning,

applying the clustering categories to filtered documents (Figure 3). An H-index author filter was also used to optimize the balance between publications and citations [19].

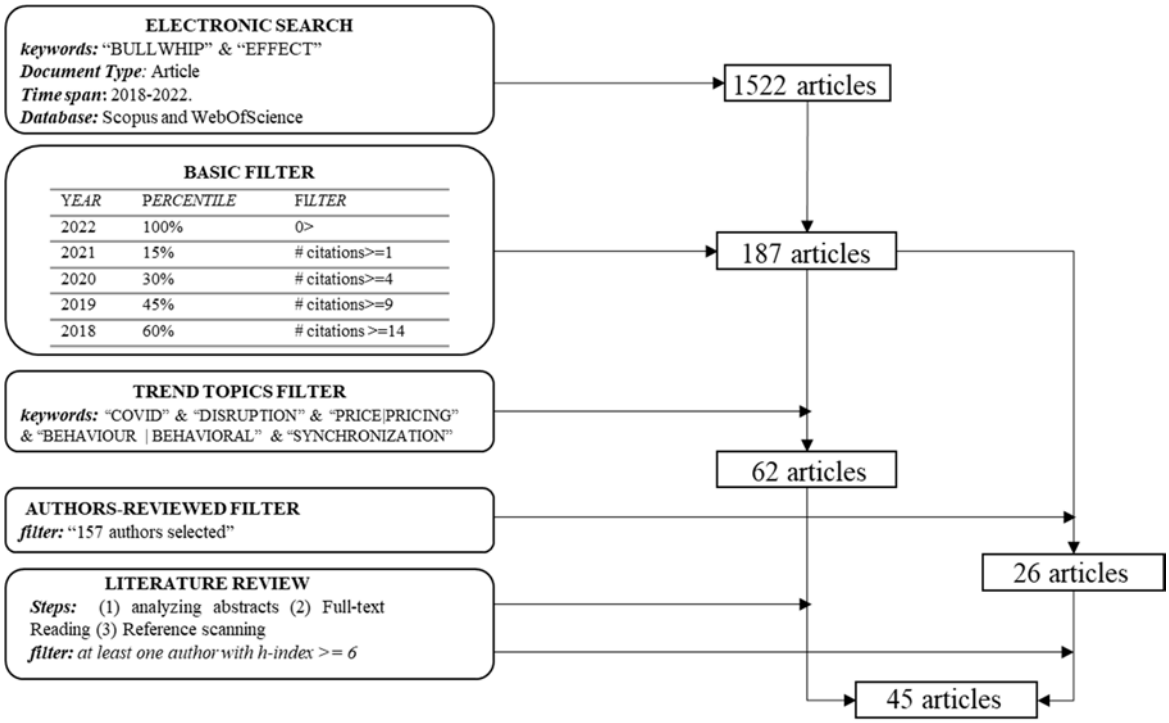

Figure 3 Refinement process

Filtering based on Category clustering: The search phase identifies papers regarding relevance and time, filtering by year, citations, trend recent topics, and authors to identify the bodies of knowledge. The basic filters include English documents from 2018 until 2022, filtering relevant studies by the number of citations using percentile values. The trend and historical topics are searched in the title, abstract, author, and keywords. The authors-reviewed filters no-trend topics studies through a bibliographic analysis of co-authorship to cluster authors with at least four published documents and follow a line of research. From the initial 2,381 authors, 157 are selected.

3 Results and discussion

This research adopts three main frameworks to identify the problem, approach, solution, result, and future studies. First, Bhattacharya et al. [15] classified the BWE into two main categories, operational and behavioral. The operational causes are characteristics inherent to the SC operation, while behavioral ones are decision-makers' reactions that increase fluctuations in the network. Second, Geary et al. [16] designed a five routes framework to reduce the BWE minimizing costs through difference equation (OR theory), a control law approach to solving fluctuations, exchanging SC structure problems to get the desired response, causal loops approach with system dynamics simulation, and previous practical experience (Ad-Hocacy). Third, Wang et al. [10] identified six trends that explain how the topics are evolving: SC structure studies from linear and simple networks to no linear and complex ones, from tangible to intangible products, financial and information flows beside the logistic ones, market power approaches including competing scenarios, sustainability including environmental perspective beyond the economic one, and the operational BWE concept incorporating finance and regulatory subjects.

3.1 Price fluctuations

The price effect on the SC's actors creates fluctuations in demand and the BWE, analyzing the price stability, price-sensitive demand streams, stochastic purchase prices, and scenarios of multiple products interacting with price-sensitive demands [20,21]. However, more studies on how price contributes to BWE propagation are needed [10,15]. Tai et al. [22] developed a linear combination autocorrelated (LCA) demand function to measure the BWE in a two-echelon SC; with an order-up-to (OUT) policy, deterministic lead time, autoregressive demand, retail prices, and customer reference prices. Price and demand correlation explains the customer's decision-making process to stockpile influenced by inventory level and retailer's actions over price reference through fluctuations and discounts; suppliers who implement promotional strategies adjusting price span can reduce the BWE. Communication of external factors influencing

reference price rather than retailer and adoption of reference price models may be explored.

Feng et al. [12] investigated disruption and panicking with price fluctuations, analyzing pricing strategies to adjust order variance through an econometric model (EM) to reduce the BWE. The "naïve" model defines price based on capacity and demand-price function, omitting customers' reactions and having the best relation between order variability and profit, followed by the historical regression prices and customer orders model. The "One-period correction" model tunes price value with customer deviation in the last period less effectively. A fixed price model eliminates order fluctuations whit non-profit results. Customer behavior deep knowledge helps to formulate the best pricing strategy under disruption. Short gaming, where limited resources influence panicking, can be explored.

Ma et al. [23] include price-sensitive and substitute products using a minimum mean square error (MMSE) demand function. A growing lead time does not increase the BWE proportionally; however, a better one enables pricing strategies to reduce it. The competitors' information improves the making-decision process and pricing strategy according to substitute product performance—a higher degree of substitution leads to more impact. The correlated influence of competitors' pricing strategies can amplify the BWE; a strong self-correlation price coefficient with a weak mutual-correlation price coefficient with competitors may amplify the BWE to the opponent. The BWE can be mitigated with a low self-correlation and high mutual-correlation price and a neutral BWE when high or low levels pair self and mutual correlation prices. Multi-substitute products, pricing strategies, and profit could be explored.

The Cash Flow BWE (CFBE) impacts competencies' conditions and market share, Chen et al. [24] compare two-parallel SC with a retailer, a supplier, two products, and an autoregressive demand process (AR). The CFBE is present in substitutable products or no-null price cross-sensitivity coefficient, improving forecast accuracy and service client increases market share and reduces CFBE. Healthy competitiveness and cooperative relationship partners decrease fluctuations. CFBE with multiple suppliers, distributors, forecasting, sales channels, and retailers may be explored.

Ponte et al. [25] provide an SC mathematical model (MM) to reflect the quantity discounts influence in the BWE and the NSA ratios by analyzing logistic costs like purchase, inventory, stock-out, opportunity, and overtime. The model optimizes discounts in upstream decision-making to implement it and downstream to calculate it. The discount encourages a mismatch in demand and orders, yielding distorted information, waste, capacity costs, and underperformed inventory. However, it could reduce purchase costs for upstream decision-makers and increase benefits for downstream SC actors. Future studies can explore: pricing strategies' influence based on markup, skimming, and penetration, Consumption psychology and pricing affecting the behavioral BWE, Closed-loop supply chain (CLSC) in pricing mechanisms, and the link between pricing decisions and disruptions like Ripple Effect (RE).

Kumar et al. [11] propose a data-driven framework to collect and process demand data and customer behavior patterns, increasing accuracy forecasting, marketing efficiency, tracking advertising, and return reductions. The historical demand is ingested and decomposed into factors to forecast future demand using seasonality and trends. The optimal demand is shaped using consumer insights, promotions, advertising, sales, pricing effects, advertising plan, and ROI to run scenarios to adjust and orchestrate the final demand. The data-driven fuzzy classifier-based (FCB) improves the forecasting process, inventory costs, and profitability, enabling a feature to evaluate hypothetical scenarios for new products. Future studies may optimize hidden layers and nodes in the fuzzy neural network model, including intermittent demand and information like weather forecasting, shipping, marketing, and customer profile.

Ma et al. [26] propose a four-channel SC network with one manufacturer and two retailers, using a price game model to simulate BWE response to changing discount conditions. The price adjustment speed and discount sensitivity infer the system's reaction. A moderate price discount keeps the system stable, but discount disruption could amplify the BWE to a chaotic state. SC actors should reduce price discount sensitivity and increase customer loyalty. Multiple channels, inventory, and discount strategies could be explored. Zhang et al. [27] simulate the BWE in a complex system with dynamic price, decision schemas, service value, and coordination process, approaching profit discrepancies in a multi-channel SC influenced by centralization levels. Centralized models have a smaller price gap between the retailer and direct channel, yielding stable market conditions. A framework to coordinate mechanisms and contract agreements under discount conditions may pair decentralized and centralized states. The BWE may increase long-term service costs. Direct channel's service value and multiple manufacturers and retailers could be explored.

Tai et al. [28] explore the price fluctuation impact on the BWE in two-echelon SC with an OUT policy and price-sensitive AR demand. The BWE is calculated with demand and order variation due to price fluctuations. A steady-limited price strategy is better for increasing demand variation. A dynamic price strategy could decrease the BWE in negative relations. This work could be extended, including deviations in the forecast and price promotions.

The trends include new flow types like strategy pricing, price sensitivity, promotions, and discounts (Table 1), adding complexity like substitute products, multiple competitors, panicking demand, marketing, financial, and customer behaviors, critical to understanding the BWE under the price lens.

Table 1 Price fluctuation literature review

Category [15]	**Solution Method.** [16]	**Technique**	**Trend** [10]	**(ME) Measure/ (MI) Mitigate**	**Sources**
O/B	OR	LCA	FTy	ME	Tai et al.[22]
O/B	OR	EM	FTy	ME & MI	Feng et al. [12]
O/B	OR	MMSE	FTy	ME & MI	Ma et al. [23]
O/B	OR	AR	FTy/C	ME & MI	Chen et al. [24]
O	OR	MM	FTy	ME	Ponte et al. [25]
O/B	CT	big data-driven FCB	FTy	ME & MI	Kumar et al. [11]
O	FT	bifurcation model	Fty/SCs	ME & MI	Ma et al. [26]
O	S	numerical simulation (NS)	Fty/SCs/MP	ME	Zhang et al. [27]
O	S	NS	FTy	ME	Tai et al. [28]

- **Category**: Operational (O), Behavioural(B).
- **Solution Method:** OR Theory (OR), filter theory (FT), control theory (CT), Simulation (S), Ad-Hocacy (AdH).
- **Trend:** SC structure (SCs), Product Type (PT), Flow Type (FTy), Market Power (MP), Sustainability (S), and Concept (C).

3.2 COVID-19, disruption, and Ripple effect

COVID-19 produced unprecedented effects in different sectors affecting downstream and upstream material flows, rethinking the globalization state, lean and local production, and risk fallbacks [29]. These fluctuations combined the demand variations due to the customers' lockdowns with a downstream propagation of the unfulfillment demand during the severe disruption, joining the BWE with the Ripple effect (RE) and affecting the SC stability significantly [30].

Dolgui et al. [31] analyze the RE influence over the BWE through discrete and agent-based simulation. The shipment, production capacity disruption, and order recoveries are simulated as discrete events, while customers and communication use agent-based and multi-agent frameworks. Supply interruptions, backorder accumulations, and late recovering periods to restore downstream flows can trigger the RE and hamper the BWE; communication and coordination reduce ordering, inventory, and production deviations. Inventory policies to control backlogs during disruption could be explored. Scarpin et al. [32] combined BWE and RE to measure the COVID-19 outbreak impact through financial and non-financial variables. The Efficient Market Hypothesis (EMH) and the Capital Asset Pricing Model (CAPM) reveal the effect on the stock market where a node represents the airline companies, comparing buyers' and suppliers' performance. Financially, BWE and RE affect more companies with high operating leverage and debt-to-assets ratio. The degree of centrality has an impact proportional to the number of suppliers and buyers. Global airline stock index (GASI) could be extrapolated to Nasdaq, S&P 500, Dow Jones, and other industries.

Ghadir et al. [33] rank COVID-19 risks, using Failure Mode and Effects Analysis (FMEA) and Best–Worst Method (BWM). The model combines Best–Worst Method (BWM) to define weights in strategies to reduce disruption. The risks include deficient customer demand information, shortages, BWE, intermittent delivery, delays, restrictions, and supply cut-off. SC visibility and information shared are crucial to reducing unpredictable market conditions' impact.

Hu [34] uses differential equations with a Markov supply-demand matrix to measure oscillations' impact and disruptions in the network, demonstrating that small fluctuations are rather than larger ones. The SC stability responds to an aligned order strategy. The Hopf bifurcation analysis calculates estimated logistic costs when the network loses the optimal point and tries to achieve it again.

Xu et al. [35] use control system theory, super-twisting (STW), and sliding mode control (SMC) algorithm to design a master entity in the system to synchronize a chaotic SC, reducing fluctuations and disturbances. Evaluating parameters like delivery efficiency, customer demand satisfaction, distortion rate, and safety stock coefficient. The model can support technology to the decision-maker. Future research can extend the scope to operations management with a depth dynamical analysis in a multi-echelon chaotic SC, using fractional-order optimal control.

COVID-19 disrupted the SC, creating an economic impact, panicking, influencing SC actors' decisions, and spreading fluctuations. Future studies can collect more information to validate current conclusions. Information sharing (IS) is insightful in reducing fluctuating conditions and uncertainty during a disruptive scenario (Table 2).

Table 2 COVID-19, disruption, and RE literature review

Category [15]	**Solution Method.** [16]	**Technique**	**Trend** [10]	**Measure/ Mitigate**	**Sources**
O	S	agent-based simulation	Fty/SCs	ME	Dolgui et al. [31]
O	OR	EMH/ CAPM	C/SCs	ME	Scarpin et al. [32]
O/B	FT	FMEA/ BWM	FTy	ME & MI	Ghadir et al. [33]
B	FT	Hopf bifurcation analysis	FTy	ME & MI	Hu [34]
O	CT	STW/SMC	FTy	ME & MI	Xu et al. [35]

3.3 Closed loop Supply chain model

The CLSC topic is growing due to an increasing interest in circular economies and their impact on profit, sustainability, and SC integration. However, there is a gap between the research and the real world to improve the current decision-making frameworks, coordinate actors efficiently, handle complex flows, and include SC dynamics [36-40]. Giri et a. [41] consider the BWE as an inventory fluctuation with large wives flowing from the consumer to the producer and replicated through the demand. The anti-bullwhip effect has an opposite dynamic, having more minor wives and not always disseminated from upstream to downstream. A variance in the market price can suppress an order amplification at each part of SC. Future studies can explore incentive systems for customers to increase the purchase of remanufacturing products, including customers' information and behaviors.

Ponte et al. [42] study a CLSC with a control system, proportional order-up-to (POUT) policy, and a quality-grading scheme to classify returning products, smoothing order rate, and BWE. A quality-grading policy increases inventory performance in low-quality returns and low-frequency demand conditioned to manufacturing and remanufacturing lead times differences. The quality-grading mechanisms benefit the work-in-progress, balancing lead time, customer service, and inventory levels; future studies: nonlinear models, remanufacturing markets, and multi-quality grades.

Dominguez et al. [43] ponder centralized or decentralized schemas in a CLSC using multi-agent-based simulation with multiple-return flows. The remanufacturer consolidates the returning flow in a centralized model, while the retailer has a remanufacturer per customer in a decentralized one. Transparency information, returning flow, remanufacturing configuration, and the number of retailers influence the BWE. A centralized model reduces reverse flow uncertainty, smoothing new product orders with operational and logistic efficiencies through information to minimize configuration effects. A decentralized model fits better in an SC with few independent markets and downstream organizations. An echelon to use reverse flow as raw material could be explored.

The CLSC is aligned with the SC structure trend (Table 3) that seeks to model the SC dynamics and return flows. The new U-shaped relations in the network create interactions, contributing to potential disturbances and fluctuations, increasing complexity, and helping to reduce costs and waste. Other BWE fields include the CLSC structure topic due to the growing interest in sustainability, complexity, and real-world problems.

Table 3 Closed-loop Supply chain model

Category [15]	**Solution Method.** [16]	**Technique**	**Trend** [10]	**Measure/Mitigate**	**Sources**
O	OR	MMSE	SCs	ME	Giri et a. [41]
O	CT	control system model	Fty/SCs	ME & MI	Ponte et al. [42]
O	S	Multi-agent-based	Fty/SCs	ME & MI	Dominguez et al. [43]

3.4 Order policy and batching

The batch size growth and unaware decisions in the order process may yield erratic dynamics in the SC and the BWE [44]. A batch size value divisor of the mean demand mitigates the BWE [45]. The policy order-up-to (OUT) has evolved to the proportional order-up-to (POUT), in which the orders are issued partially and proportional to the difference between the target and the available inventory, reducing the BWE [46-48].

Ponte et al. [49] deepen the well-known implication of batching in CLSC, being a booster for the BWE and including service level (SL). The mathematical model represents a hybrid manufacturing-remanufacturing system (HMRS) with discrete events, including inventory policies and backlogging system. The batch size should be divisors of the mean production rate [45]. Omitting the batch size increases the BWE and decreases the SL, as the OUT policy does. The POUT policy may reduce the BWE, increasing SL, inventory holding, and stock-out costs.

Cannella et al. [50] studied the POUT policy in a CLSC, decreasing the BWE. POUT policy surpasses the OUT policy with production efficiency, SL balance, and economic benefits. The OUT policy is better with high return volume and low BWE cost. Inventory controls balance the optimal difference between the target and current inventory, considering production costs, inventory, and SL. An inventory controller in the CLSC optimizes underestimated values to reduce return rates and costs.

A stochastic forecast with the POUT policy limits the BWE, satisfying the demand.

Lin et al. [51] study a push-pull hybrid system with CLSC attributes using a nonlinear control theory and discrete-time simulation. The demand frequency and return rate strongly influence the BWE due to returning orders' boomerang effect. An optimal stage linking capacity constraints to a recoverable inventory with a cost function could be explored.

Order Policy and batching size studies have increased the sophistication of the analysis by concepts like POUT policy, reduction of the BWE through the batch size divisor mean, and the influence of CLSC. The principal considerations are sustainability, finances, and SL (Table 4).

Table 4 Order policy and batching

Category [15]	**Solution Method.** [16]	**Technique**	**Trend** [10]	**Measure/Mitigate**	**Research Works**
O	OR	MM	SCs/FTy	ME & MI	Ponte et al. [49]
O	OR	difference equation	SCs/FTy	ME & MI	Cannella et al. [50]
O	CT/S	Nonlinear control/ simulation	Fty/SCs	ME	Lin et al. [51]

3.5 Information shared and synchronization

Organizations with complex-large and decentralized SCs are dynamic structures exchanging asymmetric information and lack coordination [52], adopting inefficiencies that lead to waste of resources, supply discrepancies, financial losses, and suboptimal performance [53,54]. Synchronization strategies use information sharing (IS) as the main component to align the SC at strategic, tactical, and operational levels, vertically and horizontally, to mitigate the BWE [55,56]. The collaboration schemas have two main scenarios; cooperation, where organizations have mutual commitment, goals, and dedicated resources [57]; coordination which joins the decision-making process and IS, to enhance cross-organizational performance [58].

Dominguez et al. [59] research the impact of partial, accurate, timely, and vertical IS in multi-echelons SC using the decentralized concept where not all members collaborate. Regardless of its position, the number of echelons sharing information is critical in the BWE propagation. The collaborative approach throughout IS is more effective in the downstream than upstream direction. The average lead time may reduce the BWE in IS models, particularly at upstream echelons. Future research could explore different IS types and structures with deviation.

Papanagnou [60] simulates a CLSC using a control system model to mathematically describe the complex relationships in a four-echelon network, demonstrating that high product return rates with aggressive ordering policies amplify the BWE. The model accomplished the information asymmetry in a CLSC, including the Internet of Things (IoT) concept in the customer-to-retailer loop to share accurate information about the returned products and replenishment policies to mitigate the variations in the demand and the BWE.

Ponte et al. [61] model a CLSC influenced by information transparency in order variance and inventory, defining marketing and remanufacturing archetypes with visibility levels. The return rate, lead time, and information visibility degree compose BWE functions and net stock amplification (NSA) ratio to analyze holding requirements and stock-out trade-offs with a cost structure. Increasing returns flatten production positively or negatively, depending on inventory underperformance's available information. The information transparency in the remanufacturing pipeline decreases order variance and inventory depending on market pipeline data; the market one decreases order variability and increases inventory independently. Include other forecasting models and demand attributes could be explored.

Dominguez et al. [62] simulate a four-echelon SC with a multi-agent system (MAS), with partial IS scenarios, influencing SC performance, BWE, and inventory level. Homogeneous retailers collaborating and sharing information generate equal benefits with more impact than heterogeneous ones. However, prioritizing an IS strategy benefits heterogonous retailers with poor forecasting, high demand variance, and long lead time. The full IS model should implement in highlighted retailers due to the additional costs yielded by the strategy.

Li et al. [63] represent a dynamic multi-echelon coordination scenario with material or information flows connected or interrupted. A multiagent-based framework and a consensus control system (H_∞) simulate a switching system to evaluate stock levels in sub-chains and consensus protocols. The study assesses total activation time in stable and unstabilizable subsystems, including delays in transmitting information and materials. The control technique (H_∞) mitigates the BWE mainly for isolated sub-chains, minimizing uncertainty demand. Future research could include stochastic production delays, nonlinear SC with fuzzy control, and backorders accumulated in sub-chains.

Shaban et al. [64] model a coordination mechanism to reduce the BWE through an Info-Smooth based on order smoothing and information sharing transferred upstream. The inventory policy (R,S) seeks to cover the gap between current and target inventory levels, reducing inventory variance and costs and decreasing adverse effects due to order parameters such as lead time. Future research could include order batching in collaboration models.

IS groups topics to optimize the actors' interactions and mitigate the BWE, enhancing inventory decision-making, demand management, and SC flow. Complexity is a trend in the IS (Table 5), studying the progressive amount of information shared. IS includes synchronization or schemas of collaboration to coordinate actions at different levels to mitigate the BWE, especially in disruption periods.

Table 5 Information Shared and Synchronization

Category [15]	**Solution Method.** [16]	**Technique**	**Trend** [10]	**Measure/ Mitigate**	**Sources**
O	S	computer simulation	FTy	ME & MI	Dominguez et al. [59]
O	CT	control systems model	FTy /SCs	ME & MI	Papanagnou [60]
O	OR	MM	FTy /SCs	ME & MI	Ponte et al. [61]
O	S	MAS	FTy /SCs	ME & MI	Dominguez et al. [62]
O	S	(H_∞)	FTy /SCs	ME & MI	Li et al. [63]
O	S	simulation	FTy /SCs	ME & MI	Shaban et al. [64]

3.6 Behavioral BWE

Human factors have been studied widely, such as line underweighting, phantom ordering, and coordination risk; these can be present without operational causes [65]. The BWE behavioral causes are associated with decision-makers' cognitive limitations and SC underweight [66]. SC's actors who decompose problems based on a two consecutive echelon approach tend to underestimate the BWE [67]. The BWE mitigation via behavioral factors involves an adjustment on the operational side, such as keeping inventory levels at a certain quantity [68].

Moritz et al. [69] simulate line underweighting, naïve forecasting, hoarding, phantom orders, anchoring and heuristic adjustment to classify irrational orders via experimental data, applying particle swarm (PS) optimization, beer game (BG), and cognitive reflection test (CRT). In a multi-echelon SC, decision-makers with ordering bias increase ordering costs unequally in SC actors, being worse when a retailer has it. Increasing downstream ordering raises excess inventory and logistic costs, while the upstream increases production inventory and cost to customers, reducing distributors' stock levels and decision-makers' intervention. The model rejects the naïve behavior that uses the most recent demand to forecast orders; a cognitive process shapes the making-decision process improving outcomes and reducing costs. Optimizing the forecast process can support decision-makers in disruptions with signals, data, and suggested values.

Narayanan et al. [70] use BG to design a metric-alignment framework with a coordination approach, including panicking and phantom orders. Synchronizing the decision-making process mitigates back-ordering and costs. Financial penalties related to on-time, in-full conditions to deliver orders turn a cooperative environment into a punitive one. The metric-alignment approach includes synchronization, goal congruence, and IS. In a four-echelon SC participants receive demand information from downstream partners aligned with inventory and backorder costs. Even IS reduces the BWE, unnecessary information entangles decision-making, creating sub-performance. Decision-makers' alignment with retailers mitigates the BWE, improving performance and effectiveness. Profitability, customer satisfaction, market share, SC configurations, vertical integration, and ordering incentives schema could be explored.

Shabany et al. [71] researched the negotiation process using token-based (TB) to classify current demand orders and token volume from inventory shortages; the model incorporates cooperation throughout IS where only retailers access customers' demands. The multi-agent system performs negotiation between retailer and manufacturer agents, using reverse ultimatum game (RUG) and fuzzy logic to solve ambiguities. Implementing no-bias system negotiation reduced the BWE by 30%. Developing trust variables and revenue contracts can enhance negotiation studies.

Villa [72] studied a limited supply where competitors boost placed orders volume, evaluating the BWE on supplier responsiveness, customer overreaction, and retailer efficiency through heuristics. Retailers tend to increase orders to reinforce a safety stock, expecting a shortage scenario with no signal in demand and ignoring canceled orders. The model incentivizes outstanding retailers proportional to effective orders to discourage over-stocks. Asymmetric competition's influence over decision-making, performance, and collaboration could be explored.

Xu et al. [73] simulate a chaotic four-echelon CLSC distorting sales markets and orders through differential equations, including a fractional order sliding mode control (FO-SMC) synchronization algorithm to control SC's fluctuations and tracking variances in error with a control law—a master-slave configuration with a slave system's synchronized behavior to reduce disturbances. The algorithm provides insights to the decision-makers to understand a chaotic SC and recalculate targets. Coming studies may include demand changes, promotions, and disruptions risks.

Narayanan et al. [74] run an empirical experiment to assess ordering strategies flexibility and SC underweighting. Demand variations and constrained downstream ordering limit decision-makers to handle fluctuations, impacting lead times and SL. Flexible orders

reduce variations and lead time costs, keeping the SL, and allowing decision-makers to accumulate orders irrationally. A low flexible ordering increases the cost per order, while a high one has a "minimal" one—disincentivizing irrational orders. Hard-constrained supply reduces underweighting behavior where decision-makers assess lead time to reduce order size, reducing order variation and SL. Flexible models may dampen the BWE.

Close capital relations in SC actors can build trust and benefits flow information [75]; which may lead to opportunistic or gaming behavior [76]. Zhao et al. [77] use a multivariate regression analysis (MRA) to evaluate capital relations, identify SC's links through financial statements to assess the capital relation net value, analyzing relationship length and dependency between customer and supplier. Mutual dependence increases the BWE, selling costs, order backlog shocks, and gross margin variations. However, the length of the relationships can mitigate it.

Bray et al. [78] apply a dynamic discrete mathematical model (DDMM), a Markov-modulated demand process, and a Nested Pseudo-Likelihood (NPL). The analysis identified higher variance in shipments than customers and the rational gaming action of upstream scarcity over stores accumulating stocks to avoid shortages. Rational gaming affects inventory and the BWE. SC visibility could be inadequate; the final decision depends on the decision-makers' criteria.

Operational and behavioral factors focus on physical and institutional structures. However, behavioral factors add actors' mental models, bundling rational decision-making with heuristics [7] and spreading the BWE in the SC through operational aspects. Methodologies like the beer game [79] include a holistic view of the problem to understand how behavioral and operational aspects are linked (Table 6).

Table 6 Behavioural BWE

Category [15]	**Solution Method.** [16]	**Technique**	**Trend** [10]	**Measure/ Mitigate**	**Sources**
O/B	OR/S	PS/BG/CRTt	FTy/ MP, SCs	ME & MI	Moritz et al. [69]
O/B	OR/S	BG	FTy /MP/SCs/C	ME & MI	Narayanan et al. [70]
O/B	S	TB/MAS/RUG/CBR	FTy /SCs	ME & MI	Shabany et al. [71]
O/B	OR	MM	FTy /SCs	ME & MI	Villa [72]
O/B	OR/CT	FO-ASMC/ASMC)	FTy /MP	ME & MI	Xu et al. [73]
O/B	AdH	Empirical	FTy /SCs	ME & MI	Narayanan et al. [74]
O/B	OR	MRA	FTy /SCs	ME	Zhao et al. [77]
O/B	OR	DDMM/NPL	FTy /SCs	ME	Bray et al. [78]

3.7 Lead time, demand forecasting, replenishment policies, and inventory policy

Orders are placed based on previous demand, subsequent lead times, and the amount defined by the stock policy and replenishment orders upstream. At the same time, SC's actor attempts to boost benefits regardless of overall efficiency, increasing BWE and logistic inefficiencies [80]. Deterministic or stochastic lead time influences BWE combined with different demand forecasting methods and stock and replenishment policies [81].

Michna et al. [82] measure the BWE in an SC with random autocorrelated demand and lead times, adopting the moving average method (MA) to forecast. Lead time forecasting influences BWE, increasing the stimulus when it combines forecasting and correlation demand. The volume of no-biased forecasting data is crucial to reduce the BWE. Lead time correlation and BWE propagation in a multi-echelon SC could be explored.

Dominguez et al. [83] model uncertain returns quality effects over variable lead times, inventory, and stock in CLSC through a MAS, analyzing return, information transparency, inventory performance, and the BWE. Uncertain returns fluctuations affect inventory. Avoiding the lead-time paradox where the production lead time is longer than the remanufactured one benefits CLSC performance. Incentivizing lower levels IS enhances SC's upstream performance. Order policies, stochastic returns, and returning product values determined by customer perception could be explored.

Shaban et al. [84] simulate a single-echelon SC with correlated demand, OUT policy, and returning flow, analyzing performance measures: order variance ratio (OVR), NSA, and average SL. The model includes lead time, forecasting, and order parameters. Correlated demand with OUT policy optimizes performance measures and is impacted by order parameters, tunning control parameter reduces the BWE. Future research could study time series and new adaptive forecasting methods that obey correlated demand, optimizing forecasting and order policy.

Campuzano et al. [85] research a system dynamics simulation in a single-echelon SC with variable deadlines, uncertain demand, and a rolling horizon (RH) updating information and plans, reducing inventory and logistic costs. Lot-sizing, variable lead times, and RH hence the performance, using logistic costs, SL, and the BWE as metrics. Storage and production capacities constrain the lot size, which a collaborative system such as VMI should be considered.

Bayraktar et al. [86] measure order fulfillment and the retailer's performance in a two-echelon SC with seasonal demand using discrete events, mathematics models, and SEM causal effects analysis. The retailer prioritizes SL, lead time, and forecast accuracy over the BWE; whether decision-makers underestimate backorder cost and the BWE amplification affects fill rate and total inventory cost. The decision-maker should try to decrease lead time and improve forecast accuracy; the SL seasonality affects inventory cost.

Oroojlooyjadid et al. [87] applied a BG with a reinforcement learning algorithm, comparing a basic stock policy with sub-optimal solutions and considering a decentralized information case in the decision-making process. The investigation develops a shaped-reward data-driven algorithm (SRDQR) in a cooperative environment, including information about independent actions and minimizing SC costs in the training phase. Besides, trained agents by SRDQR learn sub-optimal solutions and reduce costs compared to agents using a base-stock policy. The network design definitions may influence seasonal demand functions to increase the response [88]; Future studies can consider a network design aligned with the SRDQR framework, improving the decision-making demand process.

Disney et al. [89] studied a nonlinear inventory system with OUT policy and lost sales, comparing sales and backlogging to measure the BWE and inventory amplification and recovery. The lost sales model mitigates the BWE, contrasting with a backlogging system under some demand and forecasting conditions. No-negative conditions affect inventory variance metrics to measure control, reducing backorder accuracy or lost sales visibility. Complete demand visibility handles lost sales, out-of-stock, and total rate; the safety stock absorbs fluctuation and hidden demand from lost sales. Dynamic replenishment policies, no-linear capacity, and returns could be explored.

Lead time, demand forecasting, replenishment policies, and inventory policy studies have included CLSC structures, models, and policies. Capturing the problems' complexity results in the sophistication of some models (Table 7) proposed. Additionally, metrics like lost sales and service level balance the financial assessment, aligning the solution with different organizational objectives besides the evident economic benefit of reducing the BWE.

Table 7 Lead time, demand forecasting, replenishment policies, and inventory policy

Category [15]	**Solution Method.** [16]	**Technique**	**Trend** [10]	**Measure/ Mitigate**	**Sources**
O	OR	MA	FTy	ME	Michna et al. [82]
O	S	MAS	FTy /SCs	ME & MI	Dominguez et al. [83]
O	S	AR	FTy /SCs	ME & MI	Shaban et al. [84]
O	S	dynamic simulation	FTy	ME & MI	Campuzano et al. [85]
O	S	SEM/ discrete simulation	FTy	ME	Bayraktar et al. [86]
O	S	BG/ RL	FTy /SCs	ME & MI	Oroojlooyjadid et al. [87]
O	OR	MMSE	SCs	ME	Disney et al. [89]

3.8 Production capacity

Constrained capacity impacts lead times directly; a high volume of orders increases time and replenishment. Shrinking the capacity increases lead times, spreading fluctuations along the SC while the actors try to shield themselves from uncertain demand and periods, having a cycle that produces the BWE [90].

Cannella et al. [91] study the production capacity effect on operational performance linked to nonlinear manufacturing lead times, work in progress, and responsiveness. A two-echelon SC simulated with demand variance, safety stock, and proportional controller influencing order variance, inventory level, and SL. Opposite to other studies, increasing manufacturing capacity has positive effects by keeping a lower constant lead time, while decreasing capacity has a negative effect mitigated by SC responsiveness to work under saturation. Stochastic lead time with divergent and convergent CLSC and limited/amplified upstream affecting a downstream capacity/responsiveness could be explored.

Dominguez et al. [92] study a single-echelon CLSC with capacity restrictions and uncertainty in stock demand and returning units through differential equations, tracking the BWE on net stock and production variances. Remanufacturing forward flow fluctuations affect the whole system. Tuning correct capacity constraints, market environment, and uncertainty degree dampen BWE. However, low capacity can affect inventory holding costs and SL. Ponte et al. [93] formulate a mathematical model of impact returns in a CLSC system, considering a U-shaped dynamic between inventory performance and returns. Additionally, unknown return fluctuations affect the SC stability, increasing the BWE and the costs. The returns policy is an effective mechanism to hamper the variable effect.

CLSC schemas are linked to production capacity due to return flows and the SC dynamics' complexity fluctuations, increasing the BWE. Policies could handle these variations, funneling raw materials in the SC to reduce waste. Production capacity flexibility linked to downstream/upstream disturbances is still an open topic.

Table 8 Production capacity

Category [15]	Solution Method. [16]	Technique	Trend [10]	Measure/ Mitigate	Sources
O	OR	mathematical model	SCs	ME	Cannella et al. [91]
O	OR	difference equation	SCs	ME& MI	Dominguez et al. [92]
O	OR	mathematical model	SCs	ME	Ponte et al. [93]

4 Overlapping topics, future research, and trends

Figure 4 shows how cluster topics, BWE causes, mitigation strategies, flows, trends and future research are interconnected using the SC structure. Bhattacharya et al. [15] review is used as a framework for BWE causes, adding the trends from the closed topics, such as CLSC returning flows and COVID-19 disruptions. Forrester [94] identified three mitigation strategies: fast order handling, distributor echelon-level elimination, and inventory policy. Recently, researchers have considered lead time [95] and collaborative SC actors relationships [96] accurate forecasting [82], and pricing strategy. [28], IS [61], capacity production tunning [84], and handling CLSC returning flow [60] as strategies to mitigate the BWE. This paper used the framework proposed by Wang et al. [10] to connect trends, found concepts, and future studies discerned by authors.

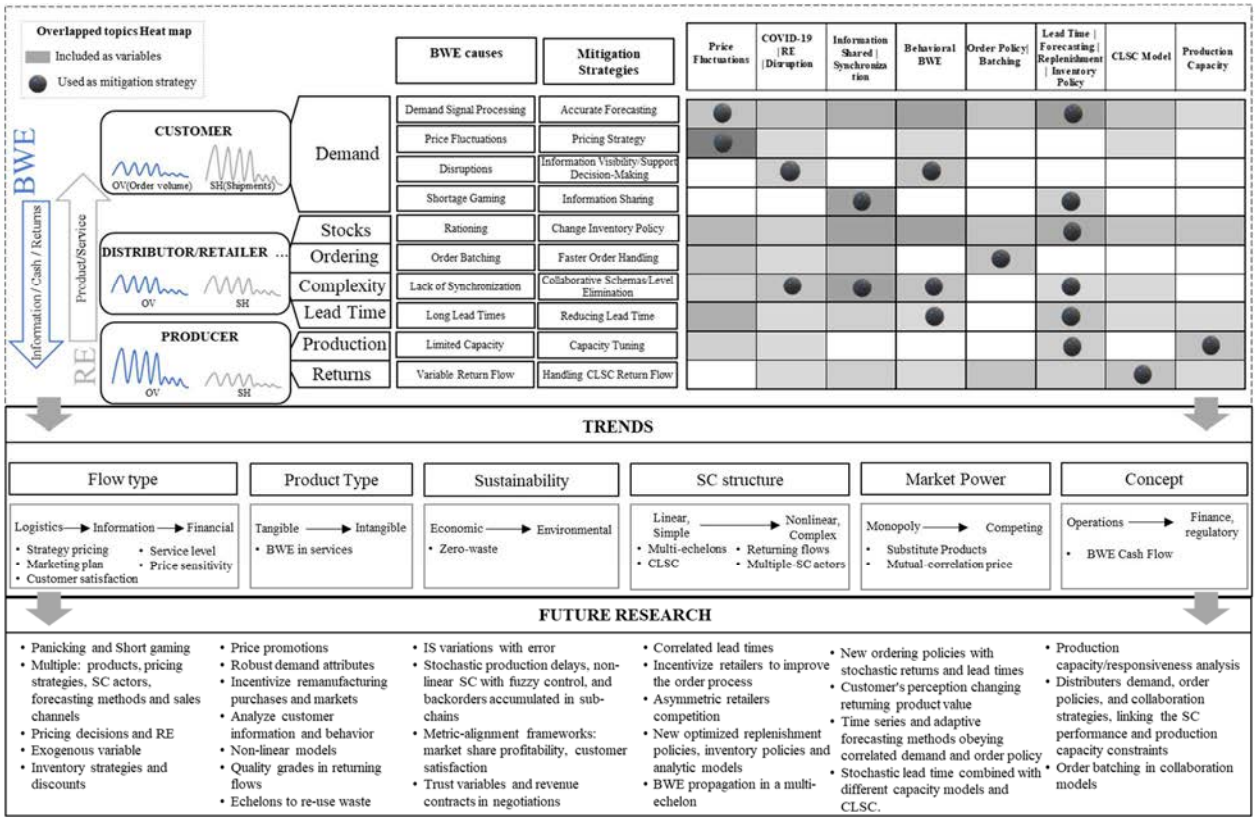

Figure 4 Overlapping topics, future research, and trends

Disney et al. [17] mapped operational and behavioral through a Venn diagram, comprehending the intersection of behavioral and operational causes. The taxonomy is updated with the new clustered topics, showing the number of behavioral studies intersected with blue numbers (Figure 5), including cross-cutting topics involved in the BWE causes.

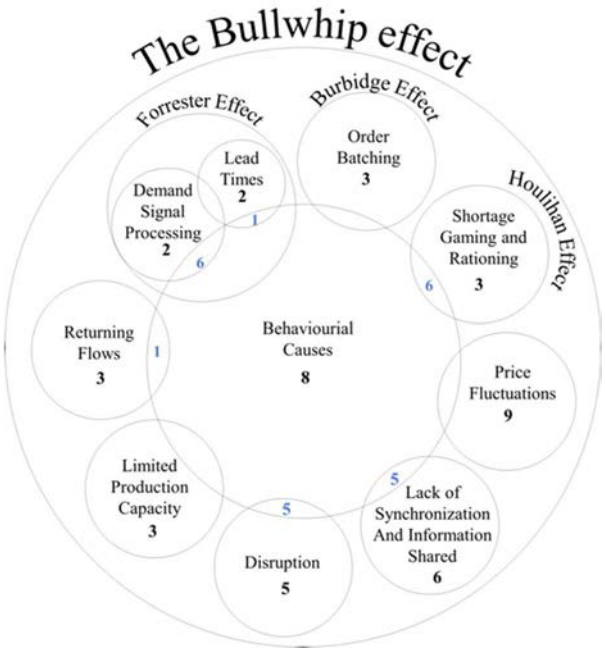

Figure 5 Overlapping behavioral and operational BWE causes [17]

5 Conclusion

How can the BWE issues be synthesized by clustering topics to illustrate existing links in the literature to identify gaps, trends, and future works?: Forecasting Demand has been the dominant topic in upstreaming variations from customers due to its relation with the BWE origin; there is an increasing necessity to improve the information collected at this point to explain and influence customers' behavior, yielding trends like pricing strategy, IS, and disruptions like the COVID-19 pandemic. At the middle network level, distributors and retailers interact through inventory policies to dampen the BWE, including order batching and lead times to further understand the ordering process factors; complexity has a relevant role, requiring collaborative schemas to sync multiple actors and changing elements. In the last level, where the BWE wave is highly amplified, adapting capacity constraints are a normal response. Nevertheless, the SC progression to CLSC models and returning flows add disturbances and new dynamics to the BWE, increasing the relevance of managing this boomerang effect.

The pricing is evolving intrinsically to strategies and complemented concepts to increase the influence over customers' behaviors. However, it is necessary to extrapolate the pricing strategy to other approaches to mitigate the BWE. Price components have been included in stocks, ordering, lead time, complexity, and production; future studies may combine it with disruptions, short gaming, IS, and CLSC schemas.

COVID-19 increased the interest in disruption topics; multiple fluctuations along the network, like BWE and RE. Information visibility and collaborative schemas mitigate the BWE in these scenarios, actively including variables from different topics. Future studies may corroborate the hypothesis around the COVID-19 disruptions, including the shortage gaming and new BWE mitigation strategies to control upstream and downstream flows influencing SC actors' behavior under panicking, like pricing, tuning capacity, and inventory policies.

Understanding and reducing returning flow disturbance is challenging in CLSC structures, representing complexity variations in some lines of research. This growing topic provides economic benefits and sustainability. Nevertheless, none of the selected papers addressed CLSC combined with pricing. There are opportunities to research more about this U-shape model, considering a new level in the SC to explore remanufacturing purchasing incentives, markets, quality classifiers, and zero-waste scenarios.

Order policy and batching include demand forecasting, stock information, and CLSC return flows as variables. Nevertheless, more BWE causes, and mitigation strategies could be linked to order batching.

The papers reviewed frequently mentioned IS to mitigate the BWE; its functionality has been strongly associated with synchronization and collaboration schemas, extending the strategy scope to influence SC actors' dynamics. There are opportunities to combine the IS with topics like pricing strategy, production capacity, and its contribution during disruption events.

The literature review found BWE behavioral causes reflected in operational factors. However, no behavioral study included order batching, shortage gaming, price fluctuations, and limited capacity. Synchronization, lead time, and information visibility were strategies to mitigate BWE. Future studies may explore ordering incentive mechanisms, competing retailers' asymmetries, promotions, and disruptions risk.

Lead time, demand forecasting, replenishment, and inventory policy influence each other, exploring the CLSC model in recent studies. Future studies could include pricing strategy, correlated and stochastic variables in demand, lead times, and non-linearities in the SC, like capacity constraints or returns. Production capacity has been a hard constraint in BWE causes and mitigation strategies. Future research may explore production capacity flexibility to handle downstream and upstream disturbances and CLSC influence over the production capacity.

Integral solutions to remove local optimizations and benefit the whole network have joined topics and sophisticated solutions to include new variables and insights to improve the SC members' decision-making processes. Complex models conceptualize problems and solutions from real-world applications.

Previous authors emphasized the opportunity to extend the BWE research to topics like pricing, behavioral BWE, financial analysis, marketing process, multi-echelon SC, inventory policies, and advanced algorithms [8,97]. This paper review recognizes emerging subjects like COVID-19

and CLSC, distinguishing them from the previous work due to the unified and updated review to visualize trends, gaps, and overlaps.

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Analysis of the usage of modern marketing strategies in commercial logistics
Annamaria Behunova, Lucia Knapcikova, Arina Vechkileva

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Analysis of the usage of modern marketing strategies in commercial logistics

Annamaria Behunova
Technical University of Košice, Faculty of Mining, Ecology, Process Control and Geotechnologies, Institute of Earth Resources, Park Komenského 19, 042 00 Košice, Slovak Republic, EU, annamaria.behunova@tuke.sk
Lucia Knapcikova
Technical University of Košice, Faculty of Manufacturing Technologies with a seat in Prešov, Department of Industrial Engineering and Informatics, Bayerova 1, 080 01 Prešov, Slovak Republic, EU, lucia.knapcikova@tuke.sk (corresponding author)
Arina Vechkileva
Technical University of Košice, Faculty of Mining, Ecology, Process Control and Geotechnologies, Institute of Earth Resources, Park Komenského 19, 042 00 Košice, Slovak Republic, EU, arina.vechkileva@tuke.sk

Keywords: modern marketing strategies, logistics, commercial logistics, competitiveness.
Abstract: In modern marketing, analysing and acting on buyers' needs is very important. Companies try to listen to the opinions of consumers because "they are always right". Marketing for commercial logistics plays an important role. All the goods in the world are transported by air, sea, pipeline, road and rail. Based on this, large logistics companies that need customer orders and customers who need their services use modern marketing strategies to sell their services. The consumer wants the company to do everything for him at the highest level. He does not turn to the first company he meets but evaluates the market and chooses the best one. The success of the company depends on which strategy the company chooses. Therefore, analysing these strategies is important for society, and only after analysing many examples used in the modern world will it not make a mistake in its choice. The research aims to analyse the innovative marketing strategies companies use in commercial logistics to sell their products and services successfully. In total, five modern marketing strategies were analysed, which are diametrically different and, due to their uniqueness, specific to different types of companies.

1 Introduction

Marketing is a foreign English word from the word we all know as "market." Otherwise, marketing can be considered as actions related to creating a market. When the word marketing began to be used frequently, after a short period, words related to marketing began to be used, such as marketing tactics, marketing strategy, marketing research, and many other expressions [1]. Marketing originated in the United States in the late 19th century and gradually developed during the 20th century. During this period, it went through developmental phases. There were 6 phases of development (Figure 1) [2]:

Figure 1 Six phases of marketing development

Marketing of the future – modern marketing strategies emerged gradually with the arrival of the new economy and a new attitude of companies towards their customers. The customer has become a determinative factor in production, transportation, and service provision, to which companies and entrepreneurs have had to adapt, including by implementing modern marketing strategies [3,4]. Modern marketing strategies differ in the approach and level of using innovative technologies, customer relationships, and services that companies offer their consumers [5,6].

Some of the most well-known and commonly used modern marketing strategies include:

- Experiential Marketing – it aims to promote the product through its features and benefits and connect it with an interesting and unique experience. The main idea of this marketing strategy is not to sell the product but to show how this particular brand of product chosen by the customer can enrich the consumer's life [7].
- Guerilla Marketing – we can classify it among the unconventional forms of marketing, which aim to

attract potential consumers so that they do not even realize that it is a promotion or advertisement, of a certain product or service, at the lowest possible cost. The basis is to be original, to have an original idea with an even more original implementation [8].

- E-marketing – we can classify this marketing strategy among the most modern. It has great potential, as today's time is full of information and communication technologies, and this strategy is mainly oriented towards online purchasing products and services [8,9].
- Product Placement – the strategy is based on placing the products of a certain brand directly in the content of a television program, film scene, or other media where this product is presented, either visually or verbally. In this way, the seller does not "annoy" the final consumer with advertisements that directly interrupt the TV program or film. Still, by watching his favourite program, the viewer subconsciously notices the products in the film [8].
- Aftermarketing – describes the new thinking that reminds marketers of the importance of building lasting relationships with consumers to extend their "lifetime" to the business. It also points to the need for a more balanced allocation of marketing funds to acquisition activities (such as advertising) and maintenance activities (such as consumer communication programs) [10].
- Word of Mouth Marketing – is popularly called word of mouth in the age of social networks. They were always there, so information was passed from one person to another based on referrals [11]. It is a viral method that spreads the word and the discussion about the product as much as possible. These conversations can take place online or offline. It can be an idea, a slogan, an advertisement, a phrase, some clever marketing move, or some push to start a discussion with people [12].
- Mass Customization – a form of production of goods and services intended for a (relatively) large market that can satisfy individual customers' individual requirements at costs that roughly correspond to the costs of making a mass-produced standardized product [13].
- Relationship Marketing – the goal is to go beyond specific products or services to achieve stronger consumer relationships. Through this type of marketing, company managers try to create a bond between customers and products, as they realize that consumers are the key to the business's long-term success [14].

Commercial logistics

A business is not a simple system but rather closely linked to its external environment through input and output flows, such as materials and information. Optimizing and integrating these external and internal flows is necessary to succeed in the market, which can be achieved through commercial logistics methods [15]. Commercial logistics is a relatively complex science that encompasses many functions. First and foremost, planning, distributing, controlling, and managing material flows is important, which are always linked to information and financial flows [15]. It absorbs various functional areas of business - purchasing, inventory, information, storage, transportation of products, and many other areas related to this particular type of logistics [16].

Commercial logistics is a relatively new direction that supports resource and product flows in production and circulation [15]. Speaking of the main goal pursued by logisticians, which is first and foremost the maximum combination of material and technical supply, followed by choosing a strategy for selling the product at a more favourable price through wholesale or retail sales, transporting various goods, which is a rather expensive process that also requires reprocessing, which concerns the information that must also be transmitted, for example, about the movement of goods, etc. [15]. The subject of commercial logistics covers the production and commercial cycle at two levels, macro and micro, which develop the most optimal methods of quality management of material, information, and financial flows [15,17]. The main problems that commercial logistics addresses in each of these areas are [15]:

- Inventory management - it is crucial to properly plan material inventory, which allows the company to quickly adapt to changes in demand, ensuring stability in the product distribution channel.
- Procurement - purchasing raw materials, materials, and semi-finished products must be carefully planned to ensure that suppliers can deliver the required quantity on time according to the company's plan.
- Product transportation - when it's time to deliver your product, which many people may be waiting for, questions arise about choosing the right transportation method, then develop a customer service schedule that satisfies everyone and ultimately deliver this product from the warehouse to the consumer.
- Warehousing - this includes the convenient location of warehouses, which is also very important for the comfortable arrival of large vehicles and the packaging of stored materials and goods.
- Information is one of the important points because it deals with processing orders, which are the "bread" for the company. Because if there are no orders, a company crisis occurs [17].

The basic principles of commercial logistics include costs and quality, which always prevail over quantity, time, and location [15].

2 Methodology

In the context of the marketing concept, three key resources are important:

1. People/employees.
2. Process.
3. Technologies.

Marketing research is based on the knowledge of various scientific fields, such as mathematics, statistics, economics, psychology, computer science and others. Technical development contributes to this to a great extent, especially in the field of information and communication systems (Figure 2).

Figure 2 Key Marketing Resources

The methodology of applying marketing to a company can be understood as a sequence of related activities or logically arranged steps.

The basic steps are:

1. Defining the research problem.
2. Data sources.
3. Methods and techniques of data collection.
4. Determination of sample size and selection.
5. Data collection.
6. Data processing and analysis.
7. Presentation of research results.

Applying marketing to the company is one of the key activities that shape the company's main goal. It also reflects the needs of the target audience-customers, from the most general level to the targeted/customized level.

3 Results

The result of the analysis we conducted is an overview of logistics companies that use innovative marketing strategies in practice. Not every strategy may be suitable for a company. Therefore, it is all individual. Company managers have the difficult task of choosing a strategy for their company that will work for the benefit of the company. A marketing strategy is necessary to achieve excellent results in the competitive market.

The research was focused on five innovative marketing strategies in practice.

Guerrilla marketing – this strategy is bold. Companies using this strategy receive criticism from their competitors. The peculiarity of this marketing is secrecy, it is used inconspicuously, but people subconsciously see it and remember it. The money spent on this marketing is average. Still, there is one peculiarity, only companies with talented marketers who are creative in promoting the company will achieve the result of this marketing. Small and medium-sized businesses often use this type of marketing; one of the reasons is the lack of money for advertising, but large companies also use it. This type of marketing requires eccentricity to attract most people's attention to the art of presenting this marketing. The manuscript describes logistics companies such as "DHL" and "FedEx"; these companies are competitive and large, and their services are used almost worldwide. "FedEx" is a bold and "arrogant" company with many competitors. Their slogan, visible on vehicles or aeroplanes of the company, "Always First", shows potential customers that they do their job faster than other competing companies. (Figure 3).

Figure 3 Guerrilla marketing of "FedEx" against competitors "DHL" and "UPS" [18]

One of the company's " DHL " marketing strategies is also Guerilla marketing. As it competes with such large companies as "FedEx" and "UPS", it must "defend" itself so that people see its importance in the market and use its services. Large companies, such as those mentioned above, invest a lot of time, energy, and money in promoting their products and maintaining their brand in the competitive market (Figure 4).

Figure 4 Guerrilla marketing of "DHL" in the underground [19]

E-marketing – a strategy that is very popular among large companies because they can spend a lot of money on online advertising. This strategy is undoubtedly effective because it uses the internet, which almost everyone can

access, which is a great advantage. It is mainly used through online stores, social networks, and YouTube. Companies grow faster with the help of email marketing. They communicate with their customers without even seeing them. For example, "Alibaba Group" and "AliExpress" are Chinese companies that sell various products. These companies use e-marketing. They have created online stores through which they sell their products. In these online stores, everyone can browse and choose the product that suits them and that they need. Their responsibilities include selling goods and delivering the product to the customer worldwide, and the delivery cost is minimal or even free, depending on current discounts. Aliexpress constantly offers its customers promotional actions and discounts on various products, attracting many consumers. Figure 5 shows how the company offers another discount on women's dresses, up to 70 %, a large selection of models, and free delivery.

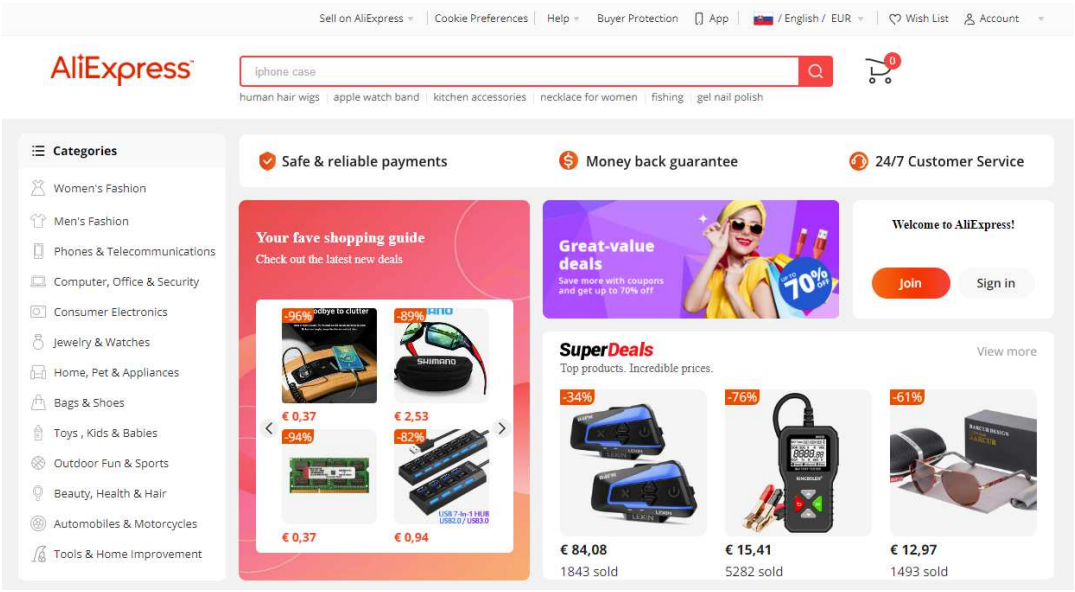

Figure 5 Example of the online store of the "Aliexpress" company [20]

In a short period, companies of this type have expanded on the market, and their competitor has also become Amazon, one of the best online platforms for selling and delivering goods worldwide. The larger the company and the larger the range of products, the more successful it is. E-marketing helps companies expand their possibilities. Alibaba Group advertises in its online store "Latest Consumer Electronics". Its essence is to attract customers to buy the latest electronics, which many are interested in. For example, as we see in Figure 6, virtual reality glasses or new headphones with excellent sound quality, many want to buy these things, but only some things can be bought at an acceptable price. Still, it is possible in stores like "Alibaba" and "Aliexpress".

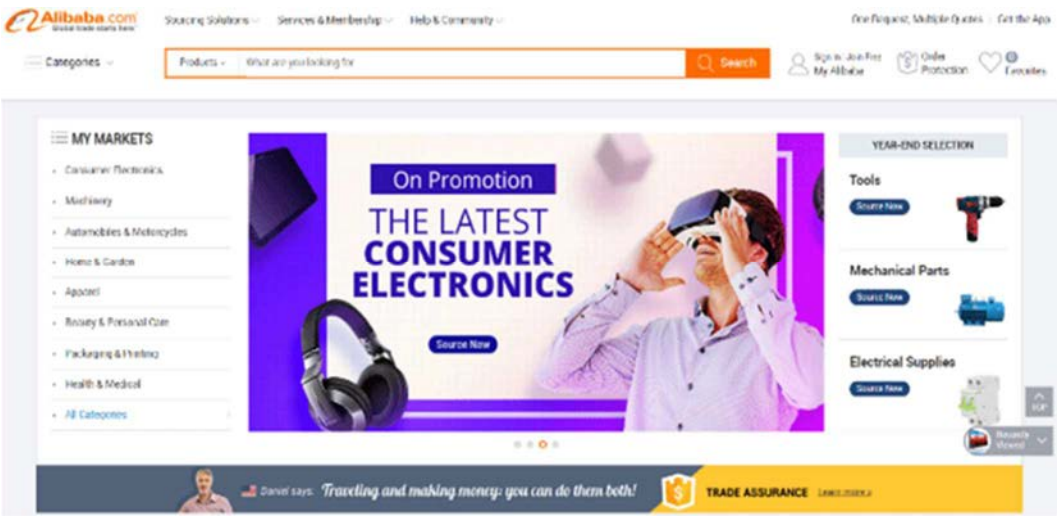

Figure 6 Example of the "Alibaba Group" online store [21]

Figure 7 shows how Amazon uses beautiful images on its online store, displays products of the day on the store's homepage and new products that have just arrived to attract potential customers and writes: "Discover millions of products and enjoy free shipping". By this, they mean that they have products for everyone. Another big advantage is the free shipping of these products worldwide right to your doorstep.

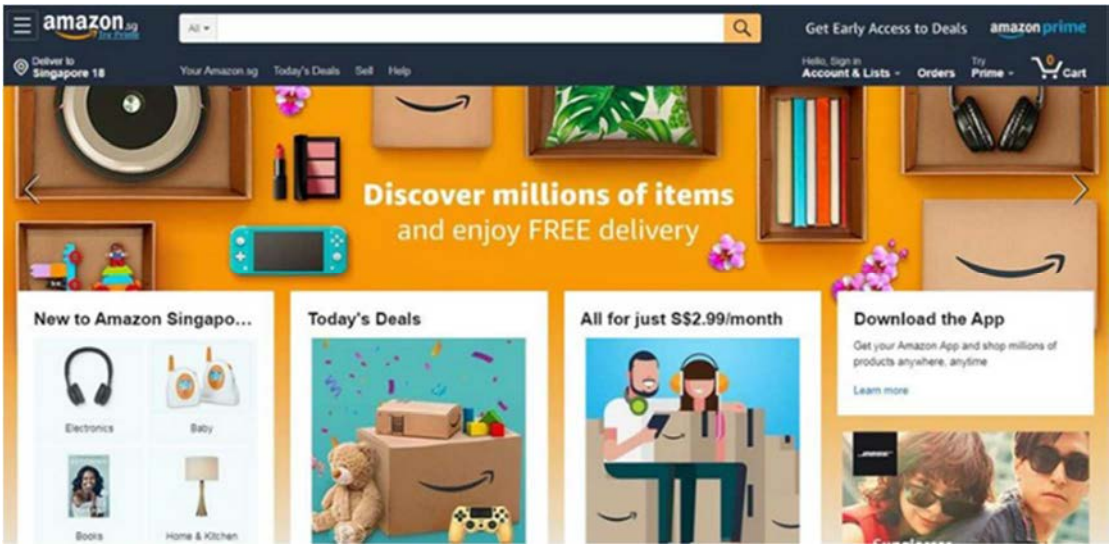

Figure 7 Example of the " Amazon" online store [22]

Relationship marketing is characterized by building strong and long-lasting customer relationships that are beneficial and pleasant for both parties. Companies utilizing this type of marketing will eventually have a good reputation. For example, DACHSER works individually with each client, much like business partners who make the best decisions for both parties. This is the main aspect of such a relationship between the company and the client, which is suitable for both parties. Therefore, there is a long-term interaction between them. The company supports customers in the purchasing and sales market, another aspect of successful cooperation. The company has a service called "DACHSER Contract Logistics", which large companies can use to manage their goods. They trust DACHSER because the company manages the storage of various goods in its warehouses. The company performs its logistics work at a high level of quality, which depends on the needs of its customers (Figure 8).

Figure 8 Service "DACHSER Contract Logistics" [23]

Another well-known company is the Indian courier company "Blue Dart", which also takes care of its customers by constantly introducing new features to make them feel comfortable. Examples of these new service features include:

- TrackDart - tracking of shipment status.
- MailDart - tracking of postal shipments.
- InternetDart - memory bank for shipments.
- PackTrack - tracking software for medium and large customers.
- ShopTrack is a tracking and CRM tool for e-commerce portals (see Figure 9).

Figure 9 Features for customer convenience of "Blue Dart" [24]

Word-of-mouth marketing, also known as oral or verbal marketing, is one of the most common and cost-effective forms of marketing. It is popular among many companies because it is a low-cost marketing method, especially for startups that are new to the market. If a product is of high quality, people will talk about it and its popularity will grow. Its effectiveness is quite high, but under one condition: if the company does its work efficiently and quickly in the case of logistics companies. Nowadays, when people spend their free time on the Internet and social media, it is easier for companies to distribute their services. Large companies that can afford to buy ads on social media platforms like Facebook, Instagram, and Twitter, where most people are, can distribute their products. People communicate with each other in this way and spread information about various companies and their products. Social media platforms are designed very competently. The information in these ads should be interesting so that people will talk about the product with their friends. In this case, when people communicate, they spread various information like a virus, which can be useful, for example, to the same companies that spend money on advertising on social media and enjoy feedback from people.

Aftermarketing, also known as post-purchase marketing, is a strategy that focuses on building a relationship with the customer after purchasing. Many companies can use this strategy, but they must decide if they can invest their time and resources into supporting their customers after selling their product or service. While a company may initially lose some resources, it can gain customers and a good reputation over time, which is more important than money in today's market. An example of such a marketing strategy is the German logistics company "DB Schenker," which offers service and after-sales logistics aimed at supporting the needs for spare parts and reverse logistics, helping to reduce maintenance and waste costs, as well as minimize costs and extend return times in the most demanding areas of the supply chain. [25]

The company provides the following services [25]:

- Exchange and warranty:
- Return to the dealer.
- Asset return.
- Waste recycling.
- Additional services:
- Visual and mechanical inspection.
- Screening.
- Technical inspection.
- Logistic services for spare parts are also available:
- Timely delivery for end-user supply chain service programs.
- Service levels over time.
- Storage services and other services such as picking, technical inspection, and packaging.
- Consolidation and optimization of transport.

The company provides these services after the sale of its goods and services are called after-sales logistics.

4 Discussion

Based on the analysis carried out, it is possible to state the following for individual marketing strategies:

Guerilla marketing is one of the most creative types of marketing, money is not the most important thing here, but the mind, creativity, and in some cases even the courage of the company, even if the company is not afraid of competition, will do aggressive marketing against its competitors. This type of marketing attracts potential customers due to its extraordinary and striking appearance; people like it because the advertisement needs to be more standard and clear.

E-marketing requires quite a lot of money in the initial stage because it needs money to create websites. Every major company uses this type of marketing because it works for today's public, who shop a lot online and see ads online. Television and radio are no longer so popular; it is more interesting to use the Internet. Such marketing is often provided through online stores and, of course, social networks. All companies are trying to break into the Internet, which is a big step for starting and developing young companies, but there is only sometimes enough money for this. Good marketing work should be meticulous concerning the client; if it is an online store, then the company is obliged to deliver the goods to the client on time because he is waiting for him and relies on the services of this company.

Relationship marketing is exactly the kind of marketing that benefits both parties. In this marketing, the analysis of the client's needs plays an important role, which gives the company a starting point, because it will help it to get closer to the client and build the kind of relationship with him that the company needs to support its services in the market. The company should always be open to communication and responsive so the client can see that the company will support and advise on the right choice. Any company can use this type of marketing because it does not require a large investment, but it takes time to communicate with the client.

Word-of-mouth advertising is the type of marketing we encounter most often; it is used through social networks and word of mouth. Initial financial contributions may be average depending on the company's size, but when a company invests in advertising, it will see results quickly in the form of orders. There are several conditions for the productive work of this strategy: a quality product and positive reviews; this will bring the company customers and success on the market. This type of marketing is very widespread, but at the same time, it needs to be aligned to remain a desired manufacturer for potential customers.

Post-purchase marketing, like relationship marketing, is very important for customers. Caring is an inherent part of this type of marketing; it "bribes" customers. When a

customer buys a product, they will be informed that they will have free support after purchasing the product. For example, a warranty for a product or service for repairing malfunctions, a toll-free telephone number where the client will be provided with comprehensive advice on issues of interest to him. Many companies use this type of marketing; there are special departments that help their customers; they try to do their work efficiently to meet customers' wishes. For companies that choose this type of marketing, it is important to support the client at a high level, for positive reviews, spreading information about their product and retaining customers.

5 Conclusions

Many modern marketing strategies help companies promote their products and services. Each strategy has some specifics, so it doesn't always "work" for every type of company. In addition, some strategies help the company and the customers; they mutually benefit. The company's task is to analyze the situation in the market, the situation in the company, and whether the company can afford a specific type of strategy. It is a difficult process, but when the company makes the right decision, it will bring the desired success in the form of new, but also the retention of regular customers.

Five modern marketing strategies were analyzed - guerilla, e-marketing, relationship, word-of-mouth, and after-marketing. Based on the analysis of these strategies, each strategy is unique and has conditions and prerequisites for the company to be effective in the market. However, before implementing a specific marketing strategy, it is necessary to analyze everything in detail. Each company has a choice of many ways to present its product, but its goal is always the same - to sell products or services. Many companies use a combination of strategies to increase their chance of success, as many more consumers can be covered with a combination. But marketing is necessary to develop a company. Big, medium, and small businesses can become competitive and profitable only because customers want quality care at a reasonable price.

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The disruptive times of Covid-19: higher education leadership and management logistics in Arab nations
Habib M. Fardoun, Ghassan Aouad, Georges Yahchouchi

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The disruptive times of Covid-19: higher education leadership and management logistics in Arab nations

Habib M. Fardoun
Canadian University Dubai, City Walk, Al Wasl, Dubai, United Arab Emirates,
habib.fardoun@cud.ac.ae (corresponding author)
Ghassan Aouad
Abu Dhabi University, Zayed City, Abu Dhabi, United Arab Emirates,
ghassan.aouad@adu.ac.ae
Georges Yahchouchi
American University of the Middle East (AUM), Egaila, 54200, Kuwait,
georges.yahchouchi@aum.edu.kw

Keywords: COVID-19, higher education, leadership and management, digital learning, online teaching.
Abstract: The COVID-19 Pandemic has changed many parts of the world, turning everything upside down in its path. Everything has changed, not just education, which has seen some unexpected changes in many places worldwide. There has been a rapid transition to online education in Arab nations due to COVID-19, which has both positives and cons. Most institutions can already adapt to education's digital teaching and learning-based future. In this study, a narrative non-systematic review methodology was used to examine the influence of COVID-19 on postsecondary education, the function of academic leaders, and the administration of Arab nations. For this investigation, a total of twenty-six pertinent scientific publications published by Arab countries were considered. Findings revealed that the psyche and emotions of students have been suffering from the limitations of the online higher education system. It was also noticed that students and teachers faced huge problems during this pandemic. The review also explored the strength of existing Middle Eastern countries' digital infrastructure facilities. Despite many limitations, instructors, institutions, and students learned many essential things during this critical COVID-19 period. Additionally, they learned how to adapt to a technology environment, which is crucial for professional success. The study's findings support the attitudes of students, teachers, leaders, managers, and other stakeholders toward online learning in challenging circumstances also in the field of logistics and transport.

1 Introduction

The COVID-19 Pandemic had a discernible impact on virtually every facet of life, but it profoundly affected educational institutions and the teaching and learning processes. The responses taken by higher education institutions to the Pandemic often fall into one of three categories: retaining in-class teaching with social distance, adopting hybrid models (blended learning, restricting the number of students on campus), or transitioning to online instruction [1]. As a safety measure against the COVID-19 risk, schools have been forced to stop all face-to-face education, including labs and other learning methods. Because of this, colleges and universities have started to take steps to prevent social isolation, and changes to the curriculum are quickly following online learning. Distributing content online is more practical since it has the potential to be a stimulating and interactive classroom. However, due to time constraints, the curriculum overhaul is expected to happen hastily and without adequate planning.

As of March 9, 2021, more than 116.5 million cases of COVID-19 and more than 2.5 million deaths from the disease had been reported worldwide. This includes Arab countries. Not only does the epidemic affect health, but it also affects social, political, economic, and religious issues [2]. In the same way, the Pandemic is affecting the education field. Scientists have been working hard to find a cure for this deadly virus, but they haven't been able to. Because of this, educational institutions have turned to online tuition methods to provide various services, such as teaching and administrative tasks. Tertiary education stakeholders must face many problems adapting to a new online environment. The right people in charge must deal with these problems as soon as possible.

Many studies have warned against confusing well-planned online learning, which requires careful instructional design, long planning, and specialized teaching infrastructure, with the quick and temporary shift to online learning during COVID-19 to keep instruction going. Different governments' solutions ranged from shuttering schools to adopting online education, and eventually leading to the development of a blended learning solution [3]. In this context, it has been argued that conflating quality online learning with emergency online learning may have a negative long-term effect on the former, as educators and students with limited or no prior experience with online learning may view it as a subpar alternative to face-to-face learning [4]. This difference is important because, despite countervailing data, online education is often seen as subpar to traditional classroom

instruction [5]. The need for pedagogical flexibility to prioritize students' well-being and access to equitable and inclusive learning settings is another key theme discussed in articles concerning the abrupt shift to online education [6]. Indeed, multiple studies have stressed the importance of educational institutions prioritizing their students' and educators' physical, mental, and psychological well-being over the necessity of teaching the curriculum [7]. After COVID-19, another set of studies looked at how students and educators viewed the growing trend of online learning. While the vast majority of these studies are limited to a single school or nation, there are also international surveys that poll students in as many as 62 different nations. These results show that, on average, students have adjusted well to the new classroom setting. Most experts, however, agree that a rich person's happiness is correlated with his or her socioeconomic level. In addition, a few of these studies highlight hurdles that could impede the efficient delivery of online education, such as the unreadiness of most institutions, faculty, and students to engage in massive and emergency online courses.

As the quantity of scientific papers grows fast, it is critical to identify the factors contributing to highly significant publications. A narrative review combined with a qualitative research methodology is beneficial in determining research findings for developing infectious disease outbreaks [8]. During the COVID-19 epidemic, several studies looked at the level of professionalism shown by school leaders and administrators as well as the challenges they faced in leading their schools with fewer people, less supplies, and greater distances between students and teachers [9]. School leaders need to be able to make quick decisions and take decisive action in times of high uncertainty in order to keep their students safe and produce great outcomes in leading for learning across a variety of delivery modalities [10]. A previous study on COVID-19 has focused mostly on analyzing the research performance of worldwide studies, but the research framework of COVID-19 in the Arab world has received far less attention. The difficulty is in ensuring that credentials gained via various educational pathways are recognized and valued equally. Distance learning must be just as good as, and lead to the same credentials as, classroom learning. In other words, there is a lack of narrative studies on COVID-19 in the Arab world that study research performance quantitatively, and the relationship between popular research themes has not been adequately documented [11]. This is a problem because COVID-19 is an important research topic. As a result, the purpose of this study was to evaluate the effect that Covid-19 has had on how Arab nations oversee the quality of their higher education systems. Because of its excellent IT (information technology) infrastructure, the higher education industry in the United Arab Emirates (UAE) was reasonably ready for the drastic change demanded by the coronavirus. The findings may uncover more effective techniques to locate an opportunity to transform the education infrastructure into a more sustainable approach. This might be made possible as a result of the findings.

In addition to the introductory section, the rest of this paper is organized as follows: State-of-the-art dealing with the most relevant and vital literature is highlighted in Section 2, and Section 3 presents the research methodology, data, and empirical models. Section 4 findings and discussions, and section 5 outlines the concluding remarks by providing concrete policy implications.

2 Research question

Taking these distinctions into account, the purpose of this study is to answer three primary research questions:

RQ1: Does COVID-19 impact the role of leaders and management in ensuring quality higher education?

RQ2: Can higher education institutions overcome critical situations like the COVID-19 Pandemic?

RQ3: Has COVID-19 provided an opportunity to transform the education infrastructure into a more sustainable system?

3 Research methodology

To conduct a review of the impact of COVID-19 on higher education in Arab nations, this review article employs a narrative non-systematic review method, which is a qualitative research method to describe and analyze Arab nations' experiences in responding to and dealing with the disruption caused by COVID-19. A non-systematic narrative review synthesizes several sources of research from which conclusions may be drawn and blends the reviewers' individual experiences and viewpoints into a thorough interpretation. The supplementary analysis based on the writers' self-awareness, reflective practice, and recognition of common educational phenomena strengthens the narrative review approach. This is due to the lack of scientific studies on the COVID-19 Pandemic's effects on higher education as well as the Pandemic's novelty and rarity.

Reviews, editorials, comments, and other relevant papers were also considered because there weren't many original, thorough empirical studies published in English. Thus, reports on the practical aspects of teaching and learning by students and professionals published in various media outlets as well as grey literature made up of opinions from experts and practitioners published in bulletins and newsletters, are included in the search. The data was collected using four significant electronic databases: EBSCOHOST, Scopus, Google Scholar, and Google WOS. The key search terms used were "COVID-19 and higher education" Higher education leadership and management during COVID-19, and "COVID-19 and online teaching in Arab countries.

Related Previous Research: Publications list related content information about online education in Arab

Nations is presented in Table 1. Our review of the table shows that COVID-19 has revealed the strategic opportunity to transform the education infrastructure into a more sustainable way for many countries, especially Arab nations. Most of the research was done in Arab countries during the mature phase of COVID-19 using case studies and surveys. Some articles also proposed a model for emergency remote learning.

Table 1 Publications list related content information about online education in Arab Nations

Study	Citation	Country	Research Stream	Method	Sectors	Key Contributions
2020 Mohmmed	[12]	Oman (Arab)	Emergency remote teaching	Proposed and implemented model	Middle East College	Illustrate the Context, Input, Process, and Product (CIPP) model for evaluating the adopted model's effectiveness and application.
2021 Arar	[13]	Kuwait, Lebanon, Morocco, Palestine, and Qatar (Arab)	Ecological school leadership in Crisis	Semi-structured interviews	School	Reported various degrees of unrest among school administrators as well as insightful information on new pedagogical and leadership approaches at their schools in the post-COVID era.
2020 Kawamorita	[14]	Middle Eastern countries (Arab)	Role of Entrepreneurial Universities in COVID-19	Propose conceptual model	University	Stating the growing influence of academic entrepreneurship and demonstrating a fruitful option for Middle Eastern policymakers.
2021 Abushammala	[15]	Oman	private higher education and COVID-19	Survey	Postsecondary private institutions	Represents the insights of the higher education system
2021 Almomani	[16]	Jordan	Student's Belief and online education in COVID-19	Online descriptive survey	University	Educate decision-makers on how students' motivation and attitudes toward online learning will impact their future goals and choices.
2020 Crawford	[8]	20 Countries	higher education intra-period digital pedagogy responses	Desktop analysis approach	University	Evaluate how well higher education can adapt to the Pandemic.
2021 Fazza	[17]	Middle East (Qatar)	Online and blended learning in higher education	case study	University	Identify major challenges to students' engagement in online learning and propose possible solutions
2020 José Sá	[11]		Higher Education and COVID-19	Content analysis	Educational institutions	Information about the opportunities and threats that COVID-19 poses to higher education at a time when the sector must rethink its leadership models, engagement channels, and pedagogical approaches in order to ensure the sector's long-term viability is provided.
2020 Tanveer	[18]	Saudi Arabia	Online Learning and Education Sector	The survey, Predictive study, and SWOT	University	Emphasize how virtual classes affect students' academic outcomes.
2020 Mahyoob	[19]	Saudi Arabia	e-Learning for EFL and COVID-19	Survey	University	Analyze the new experiences of the students in online learning

						and determine the viability of the virtual learning methods.
2022 Moussa	[20]	UAE	Students' Academic Success and Happiness Levels while COVID-19	Oxford Happiness Questionnaire (OHQ)	University	During the COVID-19 lockdown, assess the level of happiness among college students and its related to their academic progress.
2022 Vajpeyi Misra	[21]	UAE	COVID-19 and Mental Health of Minority Arab Higher-Education Students	cross-sectional study	university, academic college	Draws attention to the various, distinct issues that minority kids with low socioeconomic status confront. Campus initiatives are required to support students' emotional needs.
2020 Buheji	[22]	Bahrain, Iraq, and Russia	Emergency remote education	case study	education organizations	In the 'new normal' post-pandemic, a hybrid strategy that combines in-person and online learning is the way to go.
2021 Al-Ghurbani	[23]	Saudi Arabia	Technology in higher education during COVID-19	Questionnaire	University	Contribute to resolving the problems that the use of ICT in higher education in Saudi Arabia is facing, notably those that have emerged amid the COVID-19 Pandemic.
2021 Alsmadi	[24]	Saudi Arabia	Digitalization of learning during COVID-19	Survey	University	In the future, encourage educational institutions to digitize their course materials.
2020 Hussain	[25]	Qatar	Distance Learning During Pandemic	Case study	Internationally Accredited Undergraduate Pharmacy Program	In future academic years, share some reflection points for integrating technology-enhanced learning in distance education.
2021 Cifuentes-Faura	[26]	Spain, Oman, Nigeria, and Cambodia	COVID-19 on higher education	cross-sectional	University	Cross-cultural knowledge of how COVID-19 has impacted students' well-being, behaviors, and learning.
2021 Chaudhry	[27]	UAE	Real-time online delivery channel in crisis	Survey	Higher Education Institutions	Concerns for academics and decision-makers who advocate the success elements of e-learning delivery methods in this area.
2021 Khaoula	[28]	Morocco	Covid-19 on Higher Education	Case study	Higher Education Institutions	Provide examples of Morocco's higher education landscape.
2020 Krafft	[29]	Arab Countries	Academic challenges and COVID 19	Survey	University	Reflect impediments to research from several COVID-19 socioeconomic limitations perspectives.
2021 Alghamdi	[30]	Saudi Arabia	Higher education in the post-COVID-19 era	descriptive-qualitative research design	University	In nations like Saudi Arabia, where remote education is still infancy, students have quality access to online learning.

2020 Lily (a)	[31]	Arab countries	Distance Education to Pandemic	Propose conceptual model	Education Institutions	Examining numerous implications through the review of interviews, social media posts, and online classes.
2021 Alshaikh	[32]	Saudi Arabia	COVID-19 on the educational process	Technology–Organization–Environment (TOE) framework	University	Highlighted key issues for the higher education authorities.
2022 Lily (b)	[33]	Arab countries	Coronian Education	Observation Method	University	Produces insights to the academicians from the perspectives of coronin education's digital, domestic, and political domain in Arab countries.

Key findings of twenty-six (26) published articles on online higher education during COVID-19 in Arab nations were analyzed and tabulated in Table 1. The current research, which is based on an analysis of 26 papers about Arab countries that weren't part of any systematic evaluation, shows that COVID-19 has highlighted the strategic potential to restructure the education infrastructure of many countries in a more sustainable way. Maximum studies were conducted during the maturity period of COVID-19 in the Arab and Middle East countries with the case study and survey methods. Some articles also proposed a model for emergency remote learning.

3.1 Online platforms and lecturer transformation

Significant challenges arose when delivering online lectures utilizing various information technology devices. Teachers who formerly taught in live classrooms may need to embrace new methodologies to achieve effective teaching outcomes, impacting tertiary education quality. Furthermore, children in isolated and rural places may lack network capacity, limiting their educational opportunities. Additionally, instructors on recorded broadcast networks could encounter issues with licensing while sharing expertise. Figure 2 depicts the transition of lecturer materials for students. If the model is circular, students may join the learning cycle at any moment and continue to collect information. An online lecture, which may be given on any of the available platforms, is the starting point for the subjective delivery of education. These online lectures provide a complete overview of the topic and an opportunity for students to raise questions concerning the subject or the complete component. These online lectures are now being taped and made available to students through the intuitions platform and social media (MS Kaizala). Students who experience Internet connection problems or have restricted bandwidth can see the recorded lectures a second time.

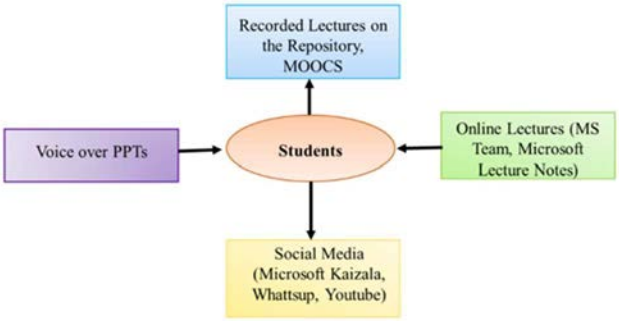

Figure 1 Transformation process of lecturer materials to the students of a Middle East College [15]

With days of the directions, many university lecturers and colleagues began investigating all accessible videoconferencing software with social media. Emails, BlueJeans, Zoom, GoToMeeting, Skype, WhatsApp, ezTalk, and the university's Moodle platform were also utilized. After hearing about the great experiences of several faculty members with the Zoom platform, the institution decided to acquire Zoom Enterprise versions for faculty usage. These versions were then integrated into the university's learning platform, Moodle, with the help of the university's software department. Now that almost all second-semester programs have been finished, there is little question that using the online method has allowed students to complete the semester even during challenging circumstances.

Table 2 demonstrates the benefits and drawbacks of various instructional delivery modes commonly used in education. However, in the present pivotal COVID-19 period, a compromise model that combines the key benefits of both instructional delivery techniques while avoiding the downsides is required. Arab nations, as a result, developed a specific framework for transformation to address these issues and guarantee the continuity of the educational process.

Table 2 Numerous online teaching approaches and their advantages and disadvantages [15]

Methods	Advantages	Disadvantages
Online classes	Students will get the chance to ask questions about the issue after receiving a thorough description.	The online courses emphasize theoretical knowledge more than practical skills, which will be challenging to acquire during the COVID-19 Pandemic.
Lecture recordings	Students having trouble connecting to the internet or having limited bandwidth can catch up using recorded lectures.	The difficulty of downloading the complete lecture will always exist due to the limited availability of Internet data. Additionally, students won't be able to suggest equations or find solutions to their previously asked questions.
PPT voice over	The main advantage of the voice-over PowerPoint slides method is that it has a small file size and uses a limited Internet connection to offer brief lesson indications on each slide.	Voice-over PowerPoint is ineffective for most theoretical explanations. Since students could find it difficult to comprehend the solution methods, voice-over PPT cannot be used to provide the majority of theoretical concepts.
MOOC	Because it was planned and prepared in advance, it provides well-structured and arranged lectures. The text typically discusses the learning objectives and outcomes.	Not all modules have it available. Additionally, some kids may have trouble enrolling because it is not free. Access to the Internet is a hurdle as well.
Via social media	Teachers and students can communicate in real-time thanks to social media sites like MS Kaizala and YouTube. It might also be used to pass along hints or make brief notes. Additionally, because it consumes the least amount of Internet traffic, it is the easiest method of communicating with students. The majority of this software is also preinstalled on the students' mobile devices.	The primary drawback would be the distraction kids experience when using social media platforms such as MS Kaizala and YouTube, where their attention is distracted. It's also difficult to have meaningful conversations or make insightful observations due to a lack of communication. Furthermore, there are tough questions about the validity of YouTube sources.

3.2 Arab country's research contribution during COVID-19

One of the researchers has researched COVID-19 regarding the Arab world's expanding contribution to international research. The United States and the United Kingdom are at the core of cooperation and have the most significant partnership with Arab nations, according to the Author's research. The 6131 COVID-19 papers had contributions from 25,562 institutions in total. A network of cooperation between Arab nations and between Arab and non-Arab nations is shown in Figure 2. The majority of COVID-19-related articles that the Author found came from Arab nations. King Abdulaziz University came in second, King Saud University in first, and Cairo University in third. Furthermore, Saudi Arabia had four of the top ten institutions, indicating that the nation has several potent research groups in this area.

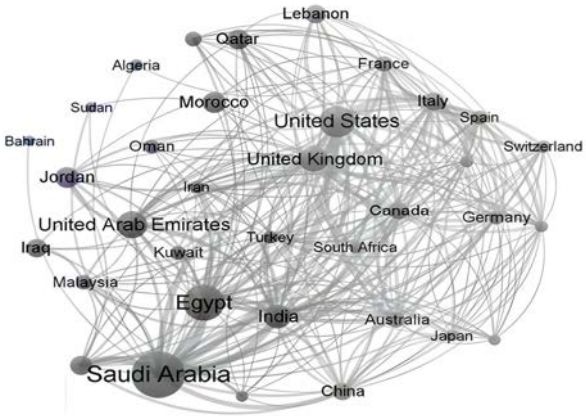

Figure 2 A network of collaboration visualization between Arab countries as well as Arab and non-Arab countries [34]

Figure 3 depicts the Arab countries' publication contributions to COVID-19, as published by Sa'ed H. Zyoud (2021). Saudi Arabia produced the most COVID-19 publications (2186, or 35.65%), followed by Egypt (1281, or 20.78%) and the United Arab Emirates (UAE), which produced 719, or 11.73%. Saudi Arabia is ranked first in this finding for output. Kuwait, Lebanon, and the United Arab Emirates are placed second, third, and fourth,

respectively. Yemen and Lebanon are rated third and eighth, respectively.

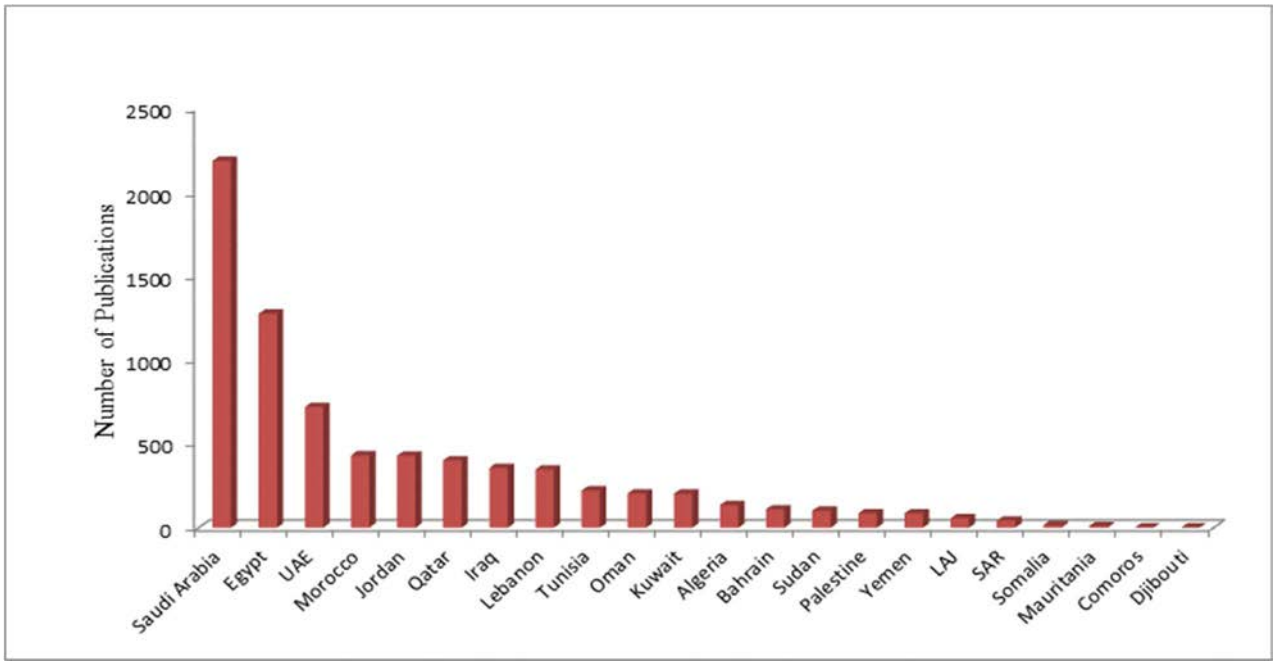

Figure 3 Involvement of Arab nations in COVID-19 research [34]
(Note: UAE = United Arab Emirates, SAR = Syrian Arab Republic, LAJ = Libyan Arab Jamahiriya)

Research on higher education students during the COVID-19 Pandemic and the role of nations was done by Deng et al. in 2021. According to this Author's finding, the figure publications are shown in Figure 4. Figure 4 depicts 110 research publications published in 31 countries during the COVID-19 crisis. The majority of the publications (51.36%) were published in China, with 9 (8.18%) coming from transnational research and 5 (4.55%) coming from the United States and Saudi Arabia. The figure in the UAE and Bangladesh is 4 (3.64%). Scholars published a minimum number of papers (1, 0.91%) in Qatar, Kuwait, Morocco, Malaysia, Italy, Lebanon, Ukraine, Egypt, Ethiopia, Pakistan, Slovakia, Switzerland, and Uganda.

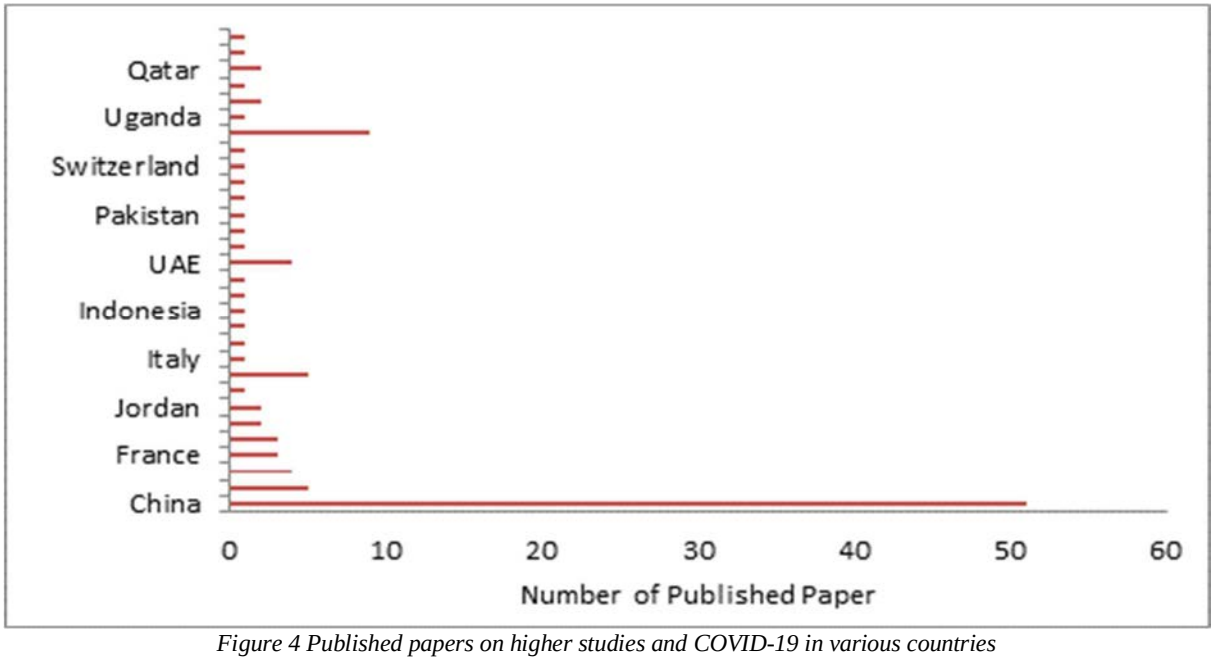

Figure 4 Published papers on higher studies and COVID-19 in various countries

4 Findings and discussions

I. Impact of COVID-19 on Arab Countries' Higher Education

With new teaching pedagogies and educational resources, COVID-19 has revolutionized the educational field. Students completed their studies through various online platforms even throughout the COVID-19 Pandemic. The results of these platforms and methods for online education vary by nation. Infrastructure, pedagogy, policy, and support from educational leadership all contribute to this diversity in educational efficacy. Due to COVID-19 and the fast transition from offline campuses to digital platforms like Google Classroom and Zoom, students have experienced various challenges. The absence of consistent internet connectivity, speed, quality, accessibility, and availability of electronic media and applications was the first barrier that students had to overcome [16]. According to the survey by Almomani et al., 80% of Jordanian students believe that the standard of instruction has declined. However, the Author also underlined that there are many successful outcomes despite the students' displeasure with educational methods. The students adapted modern information and communication resources, including Wikipedia and encyclopedia databases, YouTube videos, and eBooks.

Additionally, in a study from 2021 showed that using online resources for learning requires students to put in extra time and effort. Another issue for international students confined to dorms, because they cannot return to their home countries is their inability to pay tuition. Due to the absence of lab classes, education quality has dropped. Using online learning platforms also creates an imbalanced workload and makes it impossible to track students' learning progress. According to another author, the home environment can hinder students' ability to study and retain information due to a lack of focus and discipline. This is just another consequence of home-based, distance learning. Teachers' familiarity with technology and their ability to impart knowledge to pupils through electronic methods may have an influence on students. Students were impacted by the lack of access to research and laboratory practicals. This research highlights the importance of tutoring and classroom instruction in assisting students in understanding course material. Due to this barrier to innovation and research, universities will not be able to evolve into entrepreneurial units or entrepreneurial universities, enabling them to create jobs, disseminate knowledge, and promote national growth and development. Numerous studies explain the idea of university entrepreneurs being inventive through research.

The global Pandemic made it challenging to disseminate practical knowledge and disabled labs, a barrier for entrepreneurial universities. Some authors studied the difficulties entrepreneurial universities in the Middle East confront due to COVID-19. There is a dearth of private and governmental investment with difficulties in start-up management, technological transfer, incubators, and networking. A thriving economy, information transfer, and social well-being are supported by universities. Despite their budgetary constraints, colleges can operate with greater entrepreneurial enthusiasm by concentrating more on external demands and developing novel ways to impart information and instruction to students and businesses. One example is Oman, where universities are moving toward online teaching methodology using various digital tools as a last resort to the pandemic problem, state that entrepreneurial colleges contributed to the proactive stance taken by most Middle Eastern nations.

II. Management and Leadership in Universities for the Online Education System

Responding to the demands of adjusting to contemporary communication media, providing education and knowledge to its students, and training to its academia was challenging for the management and leaders. Universities in nations like Oman, Saudi Arabia, Kuwait, and the UAE used the coronavirus's effects to improve the information and communication systems that were already a component of their face-to-face curricula. The existence of private universities in nations like Oman further justifies providing educational services to students through digital platforms suggested by the Ministry of Higher Education, Research & Innovation in 2020. These private institutions have the web infrastructure in place to give audio and video lectures online since they release their coursework and course materials online. The integration of ICT into the educational process is crucial to its success.

Consequently, Oman is raising its level of technical literacy through cutting-edge technology equipment, smart devices, and computer apps [35]. The availability of electronic tools for education and communication among Oman's pupils results from the country's pervasive habit of using computers and other gadgets for interaction. A similar online platform has been established by the Jordanian Ministry of Education, allowing teachers to share their materials and students to engage in lectures through designated television channels. The Omani government is attempting to bring telecommunications and internet access to rural communities. The COVID-19 prevalence shows that underfunded organizations and less fortunate students who lack access to online learning infrastructure may respond to such a catastrophe. For example, two of the researchers questioned whether higher education institutions could handle the next era of digital learning. Egypt's private schools are using the country's preexisting internet infrastructure to provide students with access to online courses. British University in Cairo and American University in Cairo undertake online education with Moodle, Blackboard, Zoom, email, Microsoft Class Notes, and Microsoft Team Software, among other communication technologies. Although academics and students were aware of these communication channels before the pandemic, their use of all these digital tools and software has increased. These articles discuss the presence

of private universities in the Middle East. Large numbers of students attend the public universities in Cairo and Alexandria. That could make transitioning to an online education system more difficult suggested by the Ministry of Higher Education and Scientific Research in 2014. Live lecture streaming is a choice by Alexandria University, demonstrating the school's strong network, hardware, and software capabilities. The United Arab Emirates University and the University of Sharjah embraced the Blackboard platform described in The National and UAEU in 2020. With the knowledge obtained from the first e-University in the UAE, Hamdan Bin Mohammed Smart University, established in 2009 to deliver online learning easily, these Universities quickly improved in response to COVID-19. Even professors and other educators are taking part in training for using digital pedagogy and the internet to deliver education. These case studies of Oman, the United Arab Emirates, Egypt, and Jordan demonstrate how these nations utilize their developed digital infrastructure to mitigate the negative effects of COVID-19.

III. Transformation of online education through proper educational leaders and management system during COVID-19.

Planning policies and programs that can influence the establishment and execution of an online education system with high satisfaction among academia and students is crucial for educational leadership and management. Several studies conducted surveys to better understand students, and teachers' situations and the readiness of the digital infrastructure at universities. Understanding the drivers, obstacles, and opportunities facing all the stakeholders in the education sector will enable leadership and management to support the educational community. Effective results can be attained by implementing well-planned tactics and an active approach. Top-level administrators, such as the dean, provost, chancellor, and trustee, need to understand that online education is crucial to the financial health and growth of the university. Current educational leadership and management practices should be updated to include new Internet offerings. This report identifies several issues that the management and leaders of the university can address. Two significant devolved powers of any higher education institution were also covered by Tanveer et al. [18]. In his view, universities might provide online learning and teaching experiences that had engaged in education design capital if they enlisted the essential planner participation and updated and restructured the learning organizations into efficient and controlled units. Regarding this, Wenzel, Stanske, and Lieberman outline four ways firms might handle a crisis: cutting costs, sticking it out, innovating, and leaving. The only viable option for universities in the current COVID-19 crisis is innovation through the entrepreneurial engagement of staff and students to design and implement cutting-edge solutions to the exigency of providing education services online. Universities can create digital infrastructure with the money they save from campus activities and maintenance. The university's administration may require instructors to present course material to students using synchronous and asynchronous modes. so that they may focus on the topic at hand without being distracted by background noises or slow internet. He argues that in order to give their students with a quality education, educators need to acquire skills in online pedagogy and digital literacy. It may be challenging for educators and school administrators to keep tabs on student organizations and their members' activities and progress. Financial difficulties faced by institutions and students are another issue of concern. Numerous studies revealed that COVID-19 increased unemployment, which made it more difficult for students to pay their tuition. Because of this, educational administrators and leaders can set up simple payment plans or fee reductions until the crisis returns to normal. For remote learning procedures and supporting student programs, adequate money is crucial. To understand the priority of the needs, management and leadership need to be aligned in the educational unit. Due to ineffective teaching techniques and the subsequent lack of memory of the content, many students may choose to drop out of the courses. Due to their inability to handle a variety of software programs and digital technologies, students may prefer traditional teaching techniques despite the potential advantages of online education. Leadership in higher education has the power to reduce students' workload and screen time while also making essential policies and programs more engaging in the classroom. Bailey and Lee advocated locating a suitable Learning Management System (LMS) to support students' educational requirements since they saw the necessity for new technology for learning as a fearless call for leadership and management. Solutions to the challenges posed by COVID-19 and the implementation of a digital learning infrastructure in universities. The transition to online education is made through educational leaders and administration throughout COVID-19.

IV. Educational leadership and management for online education sustainability.

Leadership and management are crucial in creating a sustainable online education system by developing a comprehensive framework considering digital transition needs. Leaders can outline all the restrictions and challenges associated with the shift to online learning. Leaders can evaluate all the components and participants in the educational system and incorporate all needs at the individual, group, and organizational levels. Leaders can help if the educational system undergoes a new change and has a common vision and objectives. reiterate their emphasis on universities as people-oriented institutions where internal actors like students and academic staff and external actors like politicians, the press, quality assurance agencies, and the local community interact. Leaders must discover ways to foster teamwork despite divergent values,

cultures, ideas, and viewpoints to bring all internal and external stakeholders together to respond to the crisis. A company's leadership may orchestrate all of these moving parts to achieve a greater goal. Leadership may find it challenging to make judgments when there is a dispute over the creation of regulations and when academic institutions have various aims, standards, and processes. Therefore, academic leaders can concentrate on preventing conflicts and other small concerns among the managers and other academic personnel. Leaders can assist management in staying on track to meet a more significant organizational objective. Create a sustainable online education system to adopt sustainability leadership. Leal Filho et al. defines sustainability leadership as a process where the roles of leaders and management are distinct but complementary, as stated by Sá & Serpa. He says leaders have a crucial role in promoting these policies and programs as part of the sustainable leadership process developed by academics and politicians.

Putri, Mirzania, and Hartanto's research demonstrates the importance of leaders in establishing sustainability in organizations. by holding the organization's members accountable and in charge of achieving institutional goals using leadership techniques or modes that they find most appealing. Excessive time spent in front of screens, feelings of isolation, and inactivity are all factors that policymakers should consider. The effects of COVID-19 on Middle Eastern students' mental and physical health are demonstrated in this study. With an Equality Impact Assessment, leadership must strike a balance between all external and internal influencers without sacrificing the needs of higher education institutions for health, safety, and high-quality instruction. He added that decision-making by the leadership might be made without having an impact on the gender balance in an academic organization. The American Council on Education (ACE) suggests that all leaders in higher education interact with students and provide attention to the mental and emotional health and well-being of all stakeholders. Leaders, according to the Reimers and Schleicher paradigm, should use several channels of communication to learn about and address the issues of all stakeholders and students. There are times when the academic community, including the students, might benefit from the guidance of a leader. We want to draw attention to one more component: managers and leaders should evaluate and track educators to determine how well kids are performing regarding learning outcomes and how effectively teachers are teaching. According to Timmis et al., the assessment component of universities is still in its infancy. To meet the online education system, faculty members and academia must adapt the evaluation method.

5 Problem and benefits findings

The above discussion shows the following problems and benefits of online higher education at the Universities of Arab countries.

Problems: Digital barriers between students and staff were quickly revealed due to the lack of internet access in several communities in the hinterland regions where some students and employees reside. Additionally, students cannot access the internet using computers, laptops, or tablets that are present in the classroom. There was a lack of practical instruction for the students and enough prior training for lecturers on the demands of online learning. Because of their social isolation, they were unable to participate in lab or fieldwork for needed courses. Internet service providers' lack of preparedness for such demands and unexpectedly heavy internet traffic lead to slow internet speeds at home. When questions are asked, there is typically little to no feedback, and many students no longer contribute to the class discussion as they would in a conventional face-to-face situation. Due to power outages or connectivity issues, neither students nor teachers can complete their work on time. Students and staff frequently compromise with deadlines and even the standard anticipated of their product when they cannot use technology tools to complete their tasks promptly because of their numerous constraints. Many lecturers are compelled to use multiple-choice questions in online exams due to the restricted chances for assessment monitoring, and many students cannot use video services during some live class exercises and tests.

Many students who were accustomed to the traditional face-to-face method of instruction found the online method challenging. Some students, overwhelmed by the transition to online learning, were disrespectful to their teachers. Most students found it difficult to concentrate during online instruction because many had to finish their assignments from home, where they were exposed to various distractions and other household difficulties. The quick transition caused some students to feel worried and anxious. As a result of being overwhelmed by schoolwork and other commitments, several students discussed feelings of hopelessness, mental health issues, and even suicide at this time. As a result of the transition from traditional to online learning, computers and other portable technological devices are used extensively in our daily educational and teaching activities. As a result, numerous security flaws, virus exposure risks, hacking potentials, and other cyber-security threats exist.

Benefits: Online resources developed significantly compared to other resources because so many lecturers and students had access to online blogs, papers, websites, and other related resources. One of the benefits of moving to online education is that it allows for the recording of live courses, meetings, and other interactions in the cloud. There is a rising utilization of the available resources. Before COVID-19, Moodle and other platforms were not generally used, but they are comprehensively and

frequently used now. Upgrades to university technology include buying hardware and licensing, particularly add-ons to support the organization's Moodle and Zoom video conferencing systems. Technology and other online resources for education and learning allowed faculty and staff to investigate different learning possibilities. Professors and the university administration looked into the potential for blended learning. Working remotely enables faculty and students to remain involved outside a traditional university classroom.

6 Conclusion

Arab countries have abruptly shifted to online pedagogical education due to COVID-19, which has shown certain disparities and presented some challenges and advantages. This study helped us better understand how higher education leadership and administration contribute to learning, research, innovation, and serving the country in times of need. Most universities in Arab countries made the proactive decision to switch to a digital, touchless online system during the COVID-19 Pandemic. In this review, we looked at academic works that discuss difficulties and possibilities brought on by the COVID-19 eruption. Four significant problems are looked at concerning these difficulties. First, it is determined that students lack the confidence to use digital tools and mediums as a mode of education while juggling issues with money, mental health, and physical exhaustion. This is because of how the COVID-19 pandemic has affected universities and the productivity of both students and faculty. They also lament the quantity and quality of instruction that is declining. Issues with connectivity, internet speed, and a lack of digital infrastructure are also mentioned.

Regarding the second issue, it was discovered that before the COVID-19 epidemic, some nations, including the UAE, Kuwait, Oman, Egypt, Saudi Arabia, and Jordan, had digital education systems in place, particularly by private colleges. The third concern reveals that the Arab world was helped along the path to online education by the use of legacy digital technologies and media. Regarding the most recent concerns, it may be possible to envision a situation where strong leadership may compel all interested parties to work together toward a single organizational objective, including students, faculty, staff, researchers, corporations, and political activists. It considers both internal or on-campus concerns, such as infrastructure, staff skills and attitudes, facilities, learning resources and applications, and innovative solutions, as well as external/off-campus ones, such as technology infrastructure, Arab family culture, student attitudes, the labor market, and employers' appreciation of online learning. To create policies and programs that will promote growth and development, educational leaders and managers may find this study helpful in understanding the challenges and opportunities associated with the sustainable online digital medium of education.

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Service quality of e-hailing taxi services in Johannesburg

Adedotun Joseph Adenigbo
Department of Transport and Supply Chain Management, College Business and Economics, University of Johannesburg, Auckland Park, Johannesburg, ajadenigbo@uj.ac.za (corresponding author)
Joash Mageto
Department of Transport and Supply Chain Management, College Business and Economics, University of Johannesburg, Auckland Park, Johannesburg, joashm@uj.ac.za
Hemisha Makan
Department of Transport and Supply Chain Management, College Business and Economics, University of Johannesburg, Auckland Park, Johannesburg, hemisham@uj.ac.za
Rose Luke
Department of Transport and Supply Chain Management, College Business and Economics, University of Johannesburg, Auckland Park, Johannesburg, rluke@uj.ac.za

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Abstract: The study examines the service quality dimensions of e-hailing taxi services for passenger flow in Johannesburg. The objective is to determine the major service quality characteristics that affect customer satisfaction for using e-hailing taxis in Johannesburg. Questionnaires were randomly distributed to 499 e-hailing taxi users in Johannesburg. This study identified and tested service quality dimensions relevant to passengers' desire for a transport service. The study added safety and affordability to the traditional five service quality factors for analysis. The data collected were subjected to exploratory factor analysis (EFA) and regression. EFA identified reliability, tangibility, safety, and empathy as the major service quality factors for e-hailing taxis in Johannesburg. It was found that these variables significantly affect customer satisfaction with e-hailing taxi services in Johannesburg. A change in reliability will contribute about 19% to customers' perception of e-hailing taxi services, 28% for tangibility, 15% for safety and 19% for empathy, respectively. The study indicates the importance of safety as a major service quality dimension of public transportation. It implies that e-hailing taxi operators need to pay attention to passengers' safety with vigilance and appropriate safety measures.

1 Introduction

Technological advancement has led to a global shift whereby a large range of products, services, and information can be accessed using smart devices. There has also been continuous growth in application-related services, from Google Maps and music to transport-related apps known as electronic-hailing (e-hailing), such as Uber, Bolt, and in-Driver [1,2]. Global Positioning systems (GPS) and advances in software applications have resulted in a growth of e-hailing transportation services, where passengers and drivers are connected using the internet [3]. The need for real-time interaction between the driver and the customer has given traction to e-hailing transportation [4]. Within Johannesburg, e-hailing services have gained a huge market due to their ability to offer people an alternative form of public passenger transport flow. E-hailing taxi services can match the public passenger flow and transportation supply [5]. Despite the popularity of e-hailing taxi services in emerging cities, especially in sub-Saharan Africa, there is limited knowledge regarding the most important service attributes to users, as well as their level of satisfaction.

The growing use of e-hailing services has led to a need to analyse consumers' opinions and satisfaction or discontent after the service is provided [6]. Understanding user satisfaction is crucial and will determine whether a service will be used again [7]. Currently, customer satisfaction is determined by rating their experience towards a driver, using a scale of 1 to 5 stars on the e-hailing apps to rate the overall service experience of users for a more in-depth understanding of what service attributes users value most [8]. Several studies on the service qualities of different economic sectors globally indicate that it has received much research attention from scholars over the years [9]. Most of the studies applied the service quality indicators popularly named SERVQUAL by [10] to analyse the dimensions of service provision and customer satisfaction.

This study extends the knowledge about service quality by using a modified SERVQUAL model to measure the perceived service quality of e-hailing taxi services. While the traditional SERVQUAL model has five dimensions, the current study added safety and affordability, which are context-relevant attributes to measure customer satisfaction. Safety includes security, which is relevant given the many reported safety and security problems in public transport services in Johannesburg. The affordability dimension is important given that many of SSA's cities, especially Johannesburg, have high-income inequalities [11]. [12] stated that the increasing growth in

motorisation results from the decreasing urban transport safety. It indicates that e-hailing taxi services will have to address the safety perception to achieve customer satisfaction. Also, the ability of the public to pay for e-hailing taxi service, which is more expensive than traditional minibus taxis, is another concern about e-hailing taxi service quality and customer satisfaction. [13] noted that many households in automobile-dependent countries such as South Africa spend more than what is affordable on transportation. Also, [14], a World Bank paper reported that the poor in cities of developing countries find it difficult to afford public transportation. So, this paper examines the service quality of e-hailing taxis and customer satisfaction in Johannesburg. The study informs e-hailing taxi service providers and drivers about the important service quality dimensions to users, thus enabling them to better meet their customers' service needs. The relevant government agencies are also informed on possible policy directions that can support the industry to meet user requirements. The study contributes to the existing knowledge by answering the following questions.
1. What are the most important service quality dimensions for e-hailing taxi service customers?
2. How do the most important service quality factors affect customer satisfaction in Johannesburg?

The paper is structured under six (6) sections. After this section, section 2 presents the literature review, while section 3 describes the methodology adopted for the conduct of the study. Section 4 provides the study results, section 5 discusses the results, and Section 6 concludes the paper.

2 Literature review

2.1 Service quality and its dimensions

Service quality has been described as a comprehensive means of evaluating a particular service in terms of customer expectations and satisfaction levels [15]. The description of service quality assumes that service quality determination is by the judgement of customers, comparing expectations with perceptions of actual service received [16]. From the consumer perspective, service quality is the difference between expected and perceived service [17]. Service quality remains an evolving concept that requires contemporary management skills to position a business favourably in the market [18]. The significant contribution of service quality to business growth is customer satisfaction and loyalty. Because of the importance of service quality to business growth, many studies measure service quality by perceived customer satisfaction, loyalty, and retention [17-20].

One of the many service quality measures is the SERVQUAL model, which measures the perceptions and expectations of five dimensions: reliability, empathy, responsiveness, assurance, and tangibility [21]. Several studies have assessed the service quality of different industries using the five dimensions. Service quality studies cover industries such as beverage industries [21], the health sector [22], libraries [23], the banking industry [17,20], auto mechanics [19] etc. However, [16] included satisfaction, trust, and commitment as additional dimensions to measure service quality from a marketing perspective. Also, [20] found access, finance, and employee competence as significant additions to service quality dimensions in the banking industry. It implies that contemporary studies in service quality may further examine the industry and context-specific attributes to measure service quality. Following [16], this study adapts the five dimensions of service quality attributes with the addition of safety, customer satisfaction, and affordability to explore the e-hailing taxi service in Johannesburg.

2.2 Transport service quality

Public transportation in Johannesburg, South Africa, is traditionally dominated by minibus taxis, buses including PUTCO, Metrobus, BRT-Rea Vaya, and trains, namely Metrorail and Gautrain [24]. The e-hailing service has become a major transport service provider serving as an alternative mobility means for public transport as well as private car users. Studies on transport service quality in Johannesburg have been published. For example, [24-26] compared the service qualities of bus and mini-bus operations. [27] measured the perception of commuters about the service quality of mini-bus operators. [28] examined the service quality of mini-bus taxi commuters, specifically referring to the violence that black females are exposed to while commuting in Johannesburg.

2.3 Research gap

Numerous studies have been conducted on the service quality of e-hailing transport services. For instance, [6] focused on augmenting the SERVQUAL model by adding the price dimension and focusing on those service quality aspects most valued by e-hailing users in Malaysia and Indonesia. Utilising the SERVQUAL model, [3] assessed the service quality of Uber drivers in Ipoh, Malaysia, to explore users' perception of e-hailing services. A study by [29] focused on service quality using the RECSA model to determine Malaysian users' intention to use e-hailing services. Within South Africa, studies about e-hailing services have centred around young people's travel behaviour and attitudes toward different modes of transport, the influence of e-hailing on urban mobility in South Africa, as well as the institutional void associated with e-hailing platforms in Colombia and South Africa [30-32].

However, there is still a scarcity of studies on transport e-hailing taxi services in Johannesburg. The few available studies related to e-hailing taxi services investigated crime [33] and employment [34]. In addition, [35] investigated the operational and labour policy framework for e-hailing services in South Africa. The existing scope of research on transport service quality in South Africa indicates the existence of a knowledge gap about the quality of e-hailing taxi services, which this study fills by investigating user satisfaction with the service quality dimensions. Hence, this study focuses on service quality by modifying the

SERVQUAL model, including safety and affordability, to investigate e-hailing taxi services in Johannesburg. This study thus contributes to the existing literature by examining the experience of commuters using e-hailing taxi services in Johannesburg, South Africa.

2.4 Theoretical review

The study reviewed two theories about service quality measurement. The first, as proposed by [10], known as the SERVQUAL model, measures the perceived service against the expected service to determine customers' satisfaction with a particular service using ten (10) dimensions. [36] retained the theory and model but reduced the service quality dimensions to five (5) and listed them as reliability, responsiveness, assurance, tangibility, and empathy. Other revisions of the model retained the construction and the five service dimensions. The second theory reviewed for this study was proposed by Cronin and Taylor [37,38]. The theory was built on the SERVQUAL model but considered performance as the only factor measuring service quality [39]. Hence, the model was named SERVPERF to investigate the perceptions of service quality as a proxy for customer satisfaction. The model measured performance using the five dimensions of SERVQUAL in place of service expectation and perception. So, this study applied the ideas of the SERVQUAL model by examining the service quality of e-hailing taxis in Johannesburg.

3 Data and method

The study is explanatory research and adopted an exploratory research design to achieve its objectives. The goal was to investigate the service quality of e-hailing taxi services to add to the existing knowledge of traditional forms of transport since research on e-hailing taxi services as a means of mobility is limited in Johannesburg. The study considered the population of Johannesburg at 5.635 million and determined the sample size using 1 over 10,000 persons living in the city. Therefore, the sample size for the study is 564. So, 564 copies of a well-designed questionnaire were produced for data collection. The data for the study were collected by sampling a total of 499 respondents in Johannesburg. The response rate is 88.5 per cent. The questionnaire was administered to the respondents randomly at various shopping centres in Johannesburg East, Central, North, South and West Rand. The respondents frequently use e-hailing taxi services to and from shopping centres. The survey was conducted using a simple random sampling technique to ensure that members of the population had an equal chance at the survey. The random technique was applied using Microsoft Excel by generating random numbers of the 564 samples. Then, the generated random numbers were assigned to each copy of the questionnaire before administration for data collection. The study surveyed adults who could independently choose their mode of public transportation in Johannesburg.

The questionnaire was presented in two sections. A section was devoted to demographic information, while the second section focused on obtaining perceptions of service quality attributes. The service quality dimensions adopted in the study are reliability, safety, affordability, responsiveness, assurance, empathy, and tangibility. Customer satisfaction was included as a variable in the questionnaire to measure the respondent's perception of their satisfaction with e-hailing taxi services in Johannesburg. Each of the dimensions has five (5) items of measurement. The study thus comprised forty (40) scale items to measure the quality of e-hailing taxi services in Johannesburg. The items were presented on a 5-point Likert scale, from 1 – Strongly Disagree to 5 – Strongly Agree. The items were presented in statement form to give respondents weight to their perception of each item under each service quality dimension.

The data analysis used two techniques – exploratory factor analysis (EFA) and regression analysis. The EFA was used to reduce the 40 items to a few orthogonal ones that will represent the remaining items to identify the most important quality service factors for Johannesburg's e-hailing taxi services. EFA employs the variance of the variables to extract the common factors that explain customer satisfaction with e-hailing taxi service quality attributes. The EFA provides information about latent factors and estimates of the correlation between observed variables and their relationships with each unobserved variable. The EFA found reliability, safety, tangibility, and empathy as the common service factors determining customer satisfaction with e-hailing taxi services in Johannesburg.

The second part of the analysis is the regression of the extracted common factors by EFA with customer satisfaction. The regression model determines the extent and significance of the relationship between the extracted common factors and customer satisfaction. The data employed for the regression analysis were created by transforming the items that load significantly on each common extracted factor. The transformation for creating and computing the new variables was done by the mean of the significant items associated with the extracted common factors. Specifically, the mean of the items that form each common service quality factor was used to create new variables: reliability, safety, tangibility, empathy, and customer satisfaction. The regression analysis used customer satisfaction as the dependent variable and reliability, safety, tangibility, and empathy as the independent variables. This was done to determine how each variable affects customer satisfaction with the quality of e-hailing taxi services in Johannesburg.

The regression model for the study takes the form (1):

$$\boldsymbol{Y} = \boldsymbol{a} + \boldsymbol{BX_1} + \boldsymbol{B_2X_2} + \boldsymbol{BX_3} + \boldsymbol{B_4X_4} + \boldsymbol{e} \qquad (1)$$

where:
$\boldsymbol{Y}$ = dependent variable,
$\boldsymbol{B_1} - \boldsymbol{B_4}$ = coefficients of the independent variables,

$\boldsymbol{X_1} - \boldsymbol{X_4}$ = independent variables,
$\boldsymbol{e}$ = error term of the model.

Therefore, equation (1) transforms for this study as (2):

$$\text{CuSa} = \boldsymbol{a} + \boldsymbol{B_1}\text{Rel} + \boldsymbol{B}\text{Tan} + \boldsymbol{B_3}\text{Saf} + \boldsymbol{B_4}\text{Emp} + \boldsymbol{e} \quad (2)$$

where:
CuSa = Customer Satisfaction,
Rel = Reliability,
Tan = Tangibility,
Saf = Safety,
Emp = Empathy,
B = Coefficient of the independent variables,
e = Error term.

4 Results

The study focused on assessing the service quality dimensions of e-hailing taxis that influence customers' satisfaction in Johannesburg. The study determines which service quality factors are the major determinants of satisfaction for e-hailing taxi services in Johannesburg.

The output of the analysis shows that the data is adequate and suitable for EFA with a KMO test value of .967 and Bartlett's Approximate Chi-Square 15608.468, which is significant at p<0.000. The result indicates that the final output of the analysis is reliable.

The communalities of the analysis presented in Table 1 show that all the study items will significantly contribute to the reduced e-hailing taxi service quality factors. This reflects the communalities result showing that the least value after extraction is greater than .500 (See Table 1). The values representing the variance of the items is the data's communalities. The communalities are determined by adding the squared loading values of the initial and extracted loadings. The values of the extracted communalities show that all the items have an acceptable variance that can explain the variability in the common factors for e-hailing taxi services in Johannesburg, except item A4, with .187 after extraction. It implies that item A4 will produce an insignificant contribution to the common service quality factors for e-hailing taxis in Johannesburg.

Table 1 Communalities of items for e-hailing taxi services

Indicators	Description of indications	Initial	Extraction
Reliability			
R1	When e-hailing taxi service providers pledge to resolve complaints within a specified time frame, they deliver.	.565	.544
R2	When you have a grievance, the taxi service provider is sincerely interested in solving it.	.595	.575
R3	The taxi driver will arrive on time for pickups and drops.	.625	.592
R4	The taxi driver understands the routes and locations for pickups and drops.	.613	.537
R5	There is convenience in taxi booking and taxi boarding (Ease, speed, vehicle availability).	.654	.577
Safety			
S1	Taxi service providers have convenient payment options.	.572	.582
S2	There is a low probability of an accident occurring.	.694	.695
S3	There is a low possibility of injury because of reckless driving.	.648	.663
S4	There are appropriate safety measures for both the client and the driver.	.743	.760
S5	Enough safety measures are taken, and the driver is vigilant.	.702	.716
Affordability			
A1	Fares are affordable.	.667	.581
A2	Fares guarantee value for your money.	.695	.602
A3	Fares are worth the efficiency that comes with e-hailing services.	.688	.612
A4	I can consistently afford the services weekly.	.276	.187
A5	Discount(s) is offered by e-hailing service.	.600	.532
Responsiveness			
RE1	The taxi service provider will notify the customer when passenger pickup or drop will be performed.	.651	.539
RE2	The taxi service provider will give prompt services to the customers.	.651	.578
RE3	Taxi drivers will never be too stubborn or busy to respond to customer requests.	.635	.583
RE4	The e-hailing taxi offers 24-hour service quality all the time.	.622	.552
RE5	Drivers are willing to answer the questions of customers.	.641	.607
Assurance			
AA1	Drivers are professional and follow traffic rules and regulations.	.700	.605
AA2	You feel safe and secure when riding a taxi.	.732	.638

AA3	Drivers are consistently courteous with you.	.765	.678
AA4	Price is fairly consistent, and there is value for money.	.620	.534
AA5	Taxi service providers have driver, vehicle, and customer tracing capabilities in case of any issues arise.	.649	.547
Empathy			
E1	Taxi service providers have customer feedback options, driver rating options, and customer follow-up options.	.711	.592
E2	The taxi service providers will have operating hours convenient to the customer.	.697	.624
E3	Employees/Drivers are not mean and are attentive to you.	.713	.720
E4	Taxi drivers will always be willing to assist customers (boarding and luggage).	.713	.697
E5	Taxi service providers understand your specific needs.	.763	.750
Tangibility			
T1	Taxi vehicles are modern.	.751	.742
T2	Taxi vehicles' interior and exterior is visually appealing (Clean, Comfortable, Spacious, and Attractive).	.761	.728
T3	Taxi drivers usually appear neat.	.783	.768
T4	Taxi-related materials (receipts/statements) are visually appealing.	.707	.642
T5	The process of paying bills is easy and comfortable.	.681	.645
Customer Satisfaction			
CS1	Overall, I am satisfied with service of e-hailing services.	.734	.656
CS2	The e-hailing service provider performs better compared to other service providers.	.726	.669
CS3	In general, I am happy with the e-hailing service experience.	.728	.656
CS4	Requesting a ride was simple and convenient	.684	.655
CS5	Customer support service is available, e.g., post-service queries.	.705	.642

Extraction Method: Principal Axis Factoring.

The analysis took a further step to confirm the suitability of the data for the technique by determining the total variance explained by each item to identify the number of factors that can summarily explain the service qualities of e-hailing taxis. The analysis identified five (5) variables as common factors of e-hailing taxi services in Johannesburg. The identification follows the rule that items with an initial total eigenvalue greater than one (1) significantly contribute to forming the common factors. Table 2 shows that five (5) items with an initial total eigenvalue greater than one (1) accounted for 66.5 per cent of the total variance at extraction and 62 per cent after rotation to explain Johannesburg's common e-hailing service quality factors. The total percentage contribution confirms the suitability of the common factors to represent all the items. The information in Table 2 further provides the dimension for understanding the proportions of the variance of the items that form the common service quality factors of e-hailing taxis in Johannesburg. With this, at rotation, the percentage of the variance of the first common factor explained 17.55 per cent, the second factor contributed 15 per cent, the third factor contributed 11 per cent, the fourth factor explained 10 per cent, and the fifth factor contributed 8 per cent to describe the common service quality factors of e-hailing taxis in Johannesburg.

Table 2 Percentage of Total Variance of e-hailing taxi service

	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
Factor	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	19.939	49.848	49.848	19.566	48.916	48.916	7.020	17.550	17.550
2	2.743	6.858	56.706	2.430	6.075	54.991	6.023	15.057	32.607
3	1.464	3.659	60.365	1.058	2.646	57.637	4.432	11.080	43.687
4	1.341	3.353	63.718	.992	2.479	60.116	4.047	10.118	53.806
5	1.122	2.806	66.524	.754	1.886	62.002	3.278	8.196	62.002
6	.984	2.460	68.984						
7	.930	2.324	71.309						

8	.869	2.174	73.482						
9	.834	2.085	75.567						
10	.735	1.837	77.404						
11	.651	1.627	79.032						
12	.550	1.375	80.407						
13	.519	1.298	81.704						
14	.488	1.220	82.925						
15	.447	1.118	84.042						
16	.404	1.009	85.052						
17	.387	.967	86.019						
18	.370	.925	86.944						
19	.360	.899	87.843						
20	.341	.852	88.694						
21	.333	.831	89.525						
22	.315	.789	90.314						
23	.314	.785	91.100						
24	.309	.773	91.873						
25	.277	.691	92.564						
26	.271	.678	93.242						
27	.262	.655	93.897						
28	.247	.617	94.513						
29	.239	.599	95.112						
30	.231	.578	95.690						
31	.222	.554	96.244						
32	.205	.513	96.757						
33	.198	.494	97.251						
34	.189	.474	97.724						
35	.176	.440	98.164						
36	.163	.408	98.571						
37	.162	.404	98.976						
38	.146	.365	99.340						
39	.138	.345	99.686						
40	.126	.314	100.000						

Extraction Method: Principal Axis Factoring.

The common factors were extracted with principal axis factoring and varimax rotation to identify the latent items that form the common service quality factors. The rotation was done such that the values were presented according to size. The coefficients of the variables were also suppressed to 0.600 such that items with a coefficient of less than 0.600 are considered to have little contribution to the common factors of e-hailing taxi services in Johannesburg (See Table 3). The decided threshold of 0.600 is regarded as reliable for the study, irrespective of the sample size. [40, 41] advocated that factor loadings of at least 0.6 should be regarded as reliable irrespective of the sample size. A further consideration of Table 3 shows that the most significant e-hailing taxi service qualities determining customer satisfaction are reliability, tangibility, safety, and empathy. The significance of the finding is that all the safety items in the questionnaire have the highest loading factor and significantly determine the user's expectation and service performance of e-hailing taxis in Johannesburg. It implies that the safety dimension added to the model is highly important for transport service quality measurement.

An interesting output in Table 3 is that item A1 (fares are affordable) loads under customer satisfaction. It indicates that customers find issues about the affordability of transportation prices important to their perception of service satisfaction. This may explain why affordability is not among the common service factors in Table 3. It aligns with [42], who found a significant relationship between affordability and customer satisfaction. So, it implies that the masses in developing countries perceive the affordability of public transport as service satisfaction. It indicates the incorporation of the affordability service dimension into the customer satisfaction element, implying that affordability of the service is integral to customer satisfaction. That is, if transport service is not affordable, there would be no level of satisfaction.

Another interesting result of the analysis is that all the items considered under the safety factor significantly contribute to the qualities the respondents consider

influencing their safety concerns about e-hailing taxi services. Other factors have some items excluded for their little contribution, which is considered insignificant. For customer satisfaction, CS1 was removed. For Reliability, R4 and R5 were excluded. T4 and T5 were excluded for Tangibility, and E1 and E2 were excluded under empathy. The retained items (See Table 3) significantly determine the respondents' perception of each factor.

Table 3 Rotated factors of e-hailing taxi services in Johannesburg

	Factor				
Indicators	1 – Customer Satisfaction	2 – Reliability	3 – Tangibility	4 – Safety	5 – Empathy
CS4	.670				
CS2	.652				
CS5	.643				
CS3	.620				
A1	.602				
R1		.643			
R3		.639			
R2		.636			
T1			.680		
T3			.678		
T2			.677		
S4				.834	
S5				.810	
S2				.802	
S3				.773	
S1				.673	
E3					.668
E4					.665
E5					.652
Reliability Statistics (Cronbach's Alpha)	.900	.841	.917	.910	.906

Extraction Method: Principal Axis Factoring.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 7 iterations.

The reliability statistics of the items that form the common factors with very high Cronbach's Alpha values indicate that the items for each identified common factors are reliable in determining the service quality factors of e-hailing taxis in Johannesburg.

The second aspect of the analysis examines the relationship between the major e-hailing service quality factors and customer satisfaction using regression analysis. The major e-hailing service quality found by EFA are reliability, tangibility, safety, and empathy The analysis was conducted by subjecting the four (4) common service quality factors as independent variables to measure their effect on customer satisfaction (dependent variable) with e-hailing taxi services in Johannesburg.

The descriptive statistics of the regression analysis show the mean values of the variables for the study. Customer satisfaction has the highest mean of 3.821, tangibility has 3.716, empathy has 3.665, reliability has 3.629, and safety has 3.567. The output indicates that the data have an acceptable level of normal distribution for regression analysis.

The identified e-hailing service quality factors are naturally dependent on one another by the degree of relationship the respondents attached to them. The correlations matrix in Table 4 shows that the variables have a significant relationship with one another at $p < 0.000$. The correlations between the variables are positive and imply that an increase in the unit of one variable will yield an increase in the other. So, Table 4 implies that customers will tend to derive satisfaction from e-hailing taxi services as their perception of the common service quality factors increases. It is observed from Table 4 that customer satisfaction has very high significant relationships with the independent variables except with safety with $r = .474$. Other high correlation values are between tangibility and reliability ($r = .630$) and empathy and tangibility with $r = .661$. The results in Table 4 imply that patronage of e-hailing taxi services will continue to increase due to customers' satisfaction with the service quality factors. Table 4 indicates that the common service factors are associated positively with customer satisfaction.

Table 4 Correlations matrix of e-hailing service quality factors

	CuSer	Rel	Tan	Saf	Emp
Customer Satisfaction (CuSer)	1.000				
Reliability (Rel)	.632	1.000			
Tangibility (Tan)	.692	.630	1.000		
Safety (Saf)	.474	.394	.380	1.000	
Empathy (Emp)	.650	.587	.661	.392	1.000

Table 5 presents the model summary of the multiple linear regression showing the strength of the relationship between the dependent and independent variables. The correlation coefficient, R, its square, R^2, the adjusted R^2 and the standard error of the estimate. In a regression model, the R^2 serves as the unit for measuring the predictive strength of the model. For the study, the model explains that empathy, safety, reliability, and tangibility account for most of the variance in customer satisfaction with e-hailing taxi services in Johannesburg.

Table 5 Model summary of e-hailing taxi service qualities

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.776[a]	.602	.599	.53677

a. Predictors: (Constant), Empathy, Safety, Reliability, Tangibility

The R^2 of .602 indicates that the variables explain 60.2 per cent of the variance in customer satisfaction with e-hailing taxi services in Johannesburg. It implies that 60 per cent of the changes in customers' satisfaction with e-hailing taxi services can be attributed to customers' perception of reliability, tangibility, safety, and empathy level of their service quality. The adjusted R square attempts to improve the estimation of R^2 in the population. The adjusted R square of .599 represents 59.9 per cent of the variance in the service quality factors determining customers' satisfaction with e-hailing taxi services in Johannesburg.

Table 6 provides the ANOVA test result of the regression analysis to determine whether the hypothesis that the major e-hailing service quality dimensions affect customer satisfaction should be accepted. The result shows an F-Test of 186.849 when the values of the independent variables are set at zero. The ANOVA test presents $F(4.494) = 187$ at $p = 0.000$, which brings to the conclusion that the e-hailing taxi service qualities of empathy, safety, reliability and tangibility significantly affect customer satisfaction.

Table 6 ANOVA test of e-hailing service quality factors

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	215.342	4	53.836	186.849	.000[b]
	Residual	142.333	494	.288		
	Total	357.675	498			

a. Dependent Variable: Customer satisfaction
b. Predictors: (Constant), Empathy, Safety, Reliability, Tangibility

The coefficient of the service qualities for e-hailing taxis in Johannesburg presented in Table 7 provides the estimates of the standardised and unstandardised coefficients of the regression, t-test values, significance level of the estimates and collinearity statistics of the model. The estimated coefficients to explain the effect of e-hailing taxi service qualities on customer satisfaction in this study take the "Unstandardized Coefficients B". It provides for each independent variable the predicted change in the dependent variable. So, it indicates that customer satisfaction with e-hailing taxi services will increase by 18,9%, 27.6%, 14.8% and 18.9% for every additional score for reliability, tangibility, safety, and empathy, respectively. This implies that the four major service quality indicators significantly determine customer satisfaction with e-hailing taxi services in Johannesburg.

Table 7 Coefficients[a] of service qualities factors of e-hailing taxi services in Johannesburg

	Unstandardised Coefficients		Standardised Coefficients			Collinearity Statistics	
Model	B	Std. Error	Beta	T	Sig.	Tolerance	VIF
(Constant)	.887	.115		7.748	.000		
Reliability	.189	.034	.215	5.538	.000	.536	1.864
Tangibility	.276	.034	.338	8.170	.000	.470	2.129
Safety	.148	.028	.169	5.316	.000	.798	1.254
Empathy	.189	.032	.234	5.855	.000	.503	1.986

a. Dependent Variable: Customer Satisfaction

The collinearity statistics of the analysis with the Tolerance and VIF values indicate no issue of multicollinearity with the model. The VIF value for the four variables is greater than 1.00, while their corresponding Tolerance values are more than 0.1. It implies that the regression analysis output is reliable for predicting the effect of reliability, tangibility, safety, and empathy on customers' satisfaction with e-hailing taxi services in Johannesburg.

5 Discussion of results

The flow of public passenger transport in urban centres is characterised by various land use patterns and public

infrastructure. The land use centres attract the flow of people who are public transport service passengers. However, the qualities of public transport services influenced the passenger flows to the land use centres. This study provides insight into the service quality factors that users of e-hailing taxi services consider most important to their satisfaction. High quality of service within an industry or organisation has been regarded as an essential means of building customer retention and loyalty for business growth [43,44]. It implies that an organisation or business will continue to grow as much as it can sustain high service qualities of its products based on its capacity to provide customer satisfaction and retention.

This study identified the most important service quality attributes to users of e-hailing taxis and determined the extent of their influence on satisfaction with the services in Johannesburg. The study found reliability, tangibility, safety, and empathy as important service quality dimensions that promote e-hailing taxi services and significantly influence user satisfaction in Johannesburg. Reliability has been a key dimension of assessing service qualities of public transportation in different countries. That this study found reliability as a significant service quality factor for e-hailing taxi services in Johannesburg is similar to other studies. In Nigeria, [45] found the importance of reliability for public transportation in Kogi State as customers' expectation exceeds their perceived reliability. In Ethiopia, [46] explored the passengers' satisfaction with HIGER city bus services. [47] also found the reliability and tangibility dimensions of public transport service quality as the largest contributor of service quality to customer satisfaction. The study by [48] in Malaysia also supports the finding that reliability and tangibility dimensions of service quality factors significantly affect customer satisfaction. In the UK, [49] recommended reliability improvements to increase public transport passengers' perceived satisfaction. Numerous other studies have identified reliability as a significant public transport service quality factor influencing customer satisfaction. The finding implies that e-hailing service users regard the pickups and drop-offs to be on time, the vehicles are available when required, and they can rely on the providers to resolve conflicts. When the drivers achieve the foregoing, the users are satisfied with the e-hailing taxi service. Practically, e-hailing taxi operators work round the clock, making the users call for service at any time of the day, unlike the traditional public taxi services, which do not work at night seasons.

The fact that tangibility is a major significant e-hailing taxi service quality for customer satisfaction in Johannesburg is compelling. The users consider the tangibility of e-hailing taxi services regarding the physical appearance of vehicles [50] and the drivers. This result aligns with several authors who have worked on transport service qualities in different cities [27-30]. Users of e-hailing taxi services will be satisfied with the service when the vehicles are in good condition, appear neat, and the driver is smart and professional.

Safety is a major transport service dimension, including security concerns, which this study added to assess the quality of e-hailing taxi services in Johannesburg. In fact, it is unsurprising that users of e-hailing taxi services accord significance to safety as a service quality measure. This will arise from the safety concern of the users since public transportation has a higher safety risk because it usually carries more than one non-related person in a car [51]. In line with this study, [52] applied AHP to service quality factors and found that safety has the most significant weight for bus services in the Philippines. [53] found that a significant indirect relationship exists between safety and public transport quality in selected European cities. The concern makes it important that safety should be included as a service quality indicator for public transportation. The violent attacks from traditional meter taxis, carjackings and transport-related crimes in Johannesburg make safety a smajor concern among users of e-hailing taxi services. The major e-hailing services such as Uber and Bolt have been increasing the safety measures on their apps, including a safety tool kit to make it easier for users to contact emergency services. Including safety measures make users more satisfied with the e-hailing service.

Empathy, the capacity to absorb and understand the feelings of others, is an important service quality factor of e-hailing taxis expected by the users. The finding of this study regarding empathy aligns with [54] study, which found that empathy has a cause-and-effect relationship with passengers' satisfaction with public transportation. Often, passengers demand e-hailing taxi services to meet a need, which dictates their feelings. It implies that operators of e-hailing taxi services in Johannesburg are expected to study and understand the feelings of the respective passengers, which are diverse and unique to individuals. Likewise, [52] found that reliability and empathy significantly affect public transport service quality and customer satisfaction.

Therefore, the important service quality measures of e-hailing taxi services for user satisfaction in emerging cities are tangibility, empathy, reliability, and safety. This study highlights that while the traditional SERVQUAL model applies in other industries and contexts, the e-hailing taxi industry in Africa can apply a modified four-dimension model to measure satisfaction. Thus, service quality positively affects user satisfaction with e-hailing taxi services.

6 Conclusion and recommendation

This study investigated the service qualities of e-hailing taxis and customer satisfaction in Johannesburg. The study identified the most important service quality elements to e-hailing taxi users as tangibility, empathy, reliability, and safety. Further, a positive relationship was established between service quality and e-hailing taxi service user satisfaction. The other traditional dimensions, viz. assurance and service quality responsiveness were irrelevant to user satisfaction with the e-hailing taxi service. Interestingly, the study established that customers

considered the affordability of e-hailing taxi services for satisfaction. Also, the study found safety a major quality dimension for e-hailing taxi services in Johannesburg. This is primarily due to the constant robbery and other attacks that public transportation passengers face. Therefore, the managerial policy recommendation from the study provides that e-hailing taxi companies need to pay attention to the safety of their passengers by ensuring responsive vigilance with sound safety measures to build the safety perception of prospective customers of the service. The service providers may need to employ advanced technology to enhance their safe operations.

The study contributed to the existing literature by identifying that e-hailing taxi customers consider service reliability, tangibility, safety, and empathy as the most important for their continuous patronage and satisfaction. So, this study successfully highlighted the four important service quality dimensions that need to be investigated for e-hailing taxis. The study is limited to e-hailing taxi services in Johannesburg. Further, studies can replicate the study in other cities of developed and developing nations. In addition, further studies need to investigate the significance of the four service quality dimensions in other modes of public transportation.

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Simulation of operations on the production line as a tool for making the production process more efficient

Janka Saderova
Technical University of Košice, Faculty of Mining, Ecology, Process Control and Geotechnologies, Institute of Logistics and Transport, Park Komenského 14, 042 00 Košice, Slovak Republic, EU, janka.saderova@tuke.sk (corresponding author)
Lubomir Ambrisko
Technical University of Košice, Faculty of Mining, Ecology, Process Control and Geotechnologies, Institute of Logistics and Transport, Park Komenského 14, 042 00 Košice, Slovak Republic, EU, lubomir.ambrisko@tuke.sk

Keywords: production operation, simulation, model, experiment.
Abstract: For a company to make a profit and satisfy customers' needs, it must have the correct individual processes - the production process is one of the most important. This paper proposes a solution to eliminate the problem based on identifying the cause of the blocking - idle times in several workplaces of the production line. Another goal was to determine whether increasing productivity and the number of products on the given line is possible. At the beginning of the research, a system analysis of production operations was carried out. A simulation was chosen as a tool for solving the goals. Tecnomatix Plant Simulation creates the simulation model. The model was verified by a simulation experiment that simulated the current state, and the data obtained by the analysis were used. The experiment was performed for three simulated times: 8, 16 and 48 hours. After the verification of the model, experiments were performed on the models. The paper presents the results of three experiments for a simulated time of 48 hours. Based on the experiments, it was found that in the case of shortening the work cycle at critical workplaces No.5 and No.15, it is possible to make the process more efficient - to equalise the workload of individual workplaces and increase production by 25%.

1 Introduction

The mission of the manufacturing company is to achieve the best possible profit results by eliminating losses. It is necessary to satisfy customers' needs to fulfil the requirements as best as possible. For a company to make a profit and satisfy customers' needs, it must have the correct individual processes - the production process is one of the most important. The production process comprises a series of activities of different natures (processing, transport, assembly, inspection) performed on different machines and devices. It ensures the material flow from the input to the end of the production process. Discrepancy between these activities and equipment can result in downtime. However, idle time can also be caused by other factors, such as in the case of lack of material but also the case of accumulation of material at the workplace. Compliance with these facilities and activities impacts labour productivity, product quality improvement, production process efficiency increase, cost reduction, and ultimately, customer satisfaction. Inconsistencies between these activities and equipment can result in idle time.

Productivity in the industry itself is efficiency. Efficiency refers to the resources needed to achieve the desired results. These essential sources include the time during the facility's production process and the amount of funds and energy expended [1].

This article's research subject is a production line consisting of several workplaces. This paper proposes a solution to eliminate the problem based on identifying the cause of the blocking - idle times in several workplaces of the production line. Another goal was to determine whether increasing productivity and the number of products on the given line is possible. Simulation was chosen as an auxiliary tool for solving the goals based on the analysis of the current state. Simulation modelling is an excellent tool for analysing and optimising dynamic processes.

A simulation tool has become widely used since the 1950s [2]. Simulation is a research method where we replace the object of study with a model. We experiment on the created model to accumulate information and statistics and use them in the real system [3].

Simulation on real process models aims to obtain information, one of today's most valuable sources. Simulation eliminates the need for surplus financial resources from interventions in the real system. The information thus obtained is used to evaluate and improve the modelled system [3,4]. Computer simulation methods, especially discrete event simulation (DES), are the most universal and are widely used. Currently, researchers use many simulation tools for computer simulation: ExtendSim [5], Tecnomatix Plant Simulation [6], Witness [7], FlexSim [8], ARENA [9], and more [10]. Computer simulation can be used successfully to solve problems in various fields.

The simulation was used by several authors in the solution of transport in deep and surface mining [11]. The authors [12] presented the simulation study as an efficient tool for the analysis times and costs of underground

haulage systems (railway and vehicles) that are used in the mining processes with ARENA simulation software. The study of the authors [13] describes the possibility of modelling the disconnecting process of mining wagons in the program Tecnomatix Plant Simulation using the SimTalk program.

Simulation is often used in logistics solutions: transport, handling, storage, delivery of parcels, packaging, and more. The authors present the simulation model for assessing the effectiveness of implementing a goods delivery process [14]. Software Tecnomatix Plant Simulation, paired with a genetic algorithm, was used for simulation in shipment and sorting processes to determine the number of workers needed to speed up the departure of shipments and optimise the workload of workers [15].

Authors often present simulations of production plants, processes, and lines in their works. The case study [2] carried out in a medium-sized company aimed to take the first step towards sustainable production development, eliminate bottlenecks in production and shorten the production process. The means to verify and evaluate the proposed solution was a simulation in the ExtendSim. Authors often use Tecnomatix Plant Simulation (TPL) for simulation in this case. The authors' work [16] presents a TPL simulation model consisting of five modules representing individual parts of the operation. The main module represents a complete production plant and, thus, the simulation model as a whole. The sub-modules are divided into production lines, warehouse, intermediate storage and output. Using the above modules, the authors kept the simulation clear and provided the possibility of more accessible work with individual sections or their modifications. TPL was also used in the case study to create a simulation model of the production process and test the energy consumption of selected equipment with a proposal of measures to increase the company's OEE (the overall equipment efficiency) [1]. The authors' work presents a case study on creating a virtual environment and optimising the production–assembly process in the TPL software environment [17]. The streamlining utilisation of the assembly line using TPL software was dealt with by [6]. The minimising risks in the workplace using TPL was dealt with by [18], too. The authors' work presents an integration of 3D objects into the simulation as part of the material flow [19].

2 Methodology

The simulation of the selected logistics activity consists of several steps [5]. These steps have been extended. The basic steps are described in the following points and shown in Figure 1, used in this case:

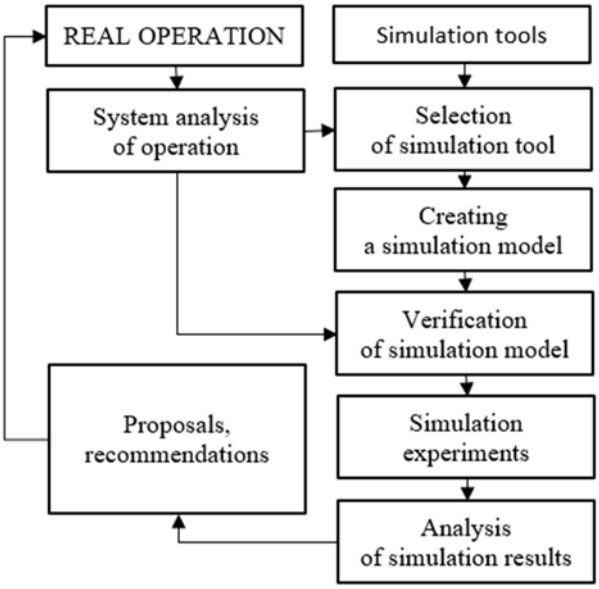

Figure 1 Steps of methodology

A: System analysis. System analysis is a suitable tool for analysing the state of the system. It examines its elements and the relationships and connections between them. Thanks to this, we can get to know the system's functioning in detail and derive individual results of observations and valuations from the research. This analytical method is used mainly in cases where we want to improve the given system or completely replace and create a new one [20,21]. The process of analysis represents the main activities: defining the problem of the production line, defining the elements and links of the production line and graphic representation, and collecting the necessary data - the observation method was used, and it is one of the time study methods and summary of findings including deficiencies. First, the observation method was used to observe the supply of the production line, individual operations, and the observation of operators. Subsequently, the method of time studies was used – "Operation snapshot" for each workplace. Operation snapshots are aimed at studying a work operation or a work cycle. To achieve reliable data, it is necessary to take the operation record several times to exclude random circumstances. The operation record is provided in several stages: preparation for monitoring and measurement, observation, measurement and recording of measured values, processing and analysis of named times - evaluation of the obtained data [22]. With the help of analysis of the system, we obtain data from operations: characteristics of the line, description of the activity on the production line, graphic representation of the sequence of activities on the production line, activity times, and definition of identified deficiencies.

B: Selection of a suitable simulation tool for creating a simulation model. Several simulation tools are currently available. Our workplace has several tools for simulating

the problem: ExtendSIM10, Tecnomatix Plant Simulation, and taraVRbuilder. Their advantage is graphic symbolism, creation of statistics, 2D and 3D animation, and flexibility when changing the model and the input data.

C: Creating a simulation model of a real system by the chosen simulation tool. The construction of the simulation model is presented in the Results.

D: Verification of the created model based on values obtained from the operation.

E: Simulation experiments to eliminate the problem on the production line. Simulation of experiments, in which the input parameters of the simulation model are changed. The task of the experiments is to see changes in the output parameters of the system.

F: Analysis of simulation results. Outputs from individual experiments (statistical parameters, performance parameters and graphical outputs) are used for analysis and behaviour of the system under changed conditions. These results need to be interpreted and used correctly.

G: Proposals, recommendations to eliminate the problem.

3 Result and discussion

3.1 The results of the system analysis

The mentioned methodology was applied to improve the efficiency of the production line. The production process consists of several technological and assembly operations on the production line at different workplaces. The selected line consists of 15 workplaces, four fully automated. There is also one preparatory workplace on this line. There are 12 production operators on the line and one worker in charge of running and servicing all four automated workplaces. This line operates in two shifts thanks to the high demand for the product.

A counter is placed at each workplace of the production line, which shows how many pieces were produced at the workplace and how many pieces should be produced at the given time according to the standard. Each workplace is equipped with a computer on which the work process at a particular workplace is displayed.

Small materials, such as screws and gaskets used in production, are placed on the worktable in small crates. Aluminium parts are stored in large crates at the workplace. More extensive materials are stored in cardboard boxes on pallets or gitterboxes along the production line. Each position includes a conveyor belt along which the product moves and a lifting device to lift the product. Each workplace has a red crate, which is intended for non-conforming material [23,24].

The sequence of workplaces where individual operations are performed is shown in Figure 2.

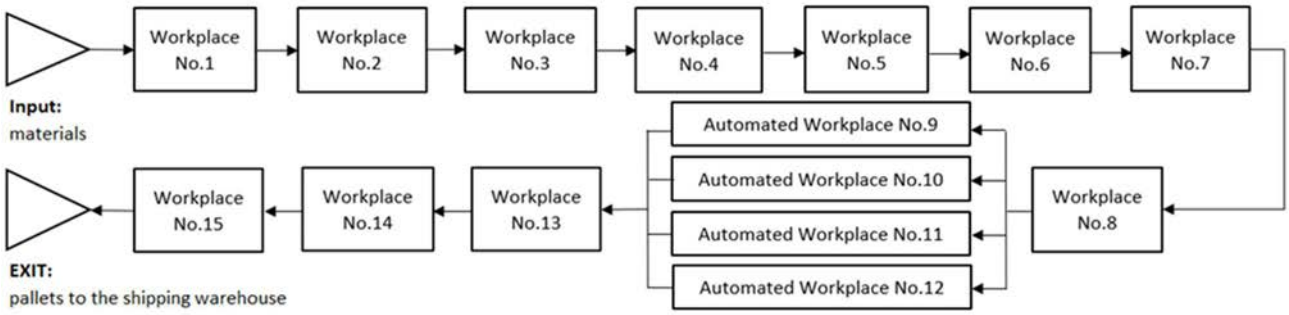

Figure 2 The sequence of workplaces

The production process on the line starts at workplace No.1 and ends at workplace No.14. The primary input material is the bare frame, on which other input materials are gradually mounted at individual workplaces. Each workplace is supplied with different input materials, except for production workplaces No. 9, No.10, No.11, and No.12, which are arranged in parallel. Here, automatic tests of manufactured products are carried out. The finished product is packed at workplace 15, loaded on a pallet and taken to the warehouse of finished products.

Assembly operations are carried out at workstations No.1 - No.7. Workplaces No.8 - No.12 are test workplaces. The assembly operation is carried out at workplace No.13, and the worker at this workplace also performs the preparatory operation for workplace No.14. At workplace No.14, the last assembly operation is performed, as well as the electrical test, which is used to check the electrical parts. Product production ends at this workplace. Workplace 15 is a packaging workplace, as mentioned above.

One of the tasks of the system analysis was:
- to observe the operation of the input material line,
- to observe individual operations on the production line,
- to record the operating times of individual operations,
- to record idle times and other irregularities,
- and, based on the observation, to define the identified deficiencies.

The analysis revealed:
- 11 input materials are used in the production of the product,

- workplaces are supplied along the marked route by a service vehicle approximately once every 40 minutes, i.e., 12 times in one shift,
- the length of work operations at workplaces No.1-No.4, No.6-No.8, No.13 and No.14 is 3 minutes and 20 seconds on average,
- the length of the work operation at workplace No.5 is 4 minutes,
- the length of the work operation at workplace No.15 is 4 minutes and 9 seconds,
- the length of work operations at workplaces No.9 - No.12 is 5 minutes, automated workplaces arranged in parallel,
- during one shift, an average of 96 pieces of finished products were produced on the production line,
- relocation of finished products from workplace No.15 is carried out using a forklift. 16 pieces of the finished product are placed on one pallet, pallets with products are transported to the output warehouse six times during one shift.

The analysis revealed the following deficiencies:

- during production, there were idle times of workers and accumulation of semi-finished products in front of workplaces No.5 and No.15 (difference in operating times),
- there were objects in the workplaces that were not necessary for the operation,
- the material and work aids used by the workers during production were not marked and did not have precise location or arrangement, the operator sometimes has to search for these aids and materials, and thus, the work cycle is extended,
- the work cycle also extends if an operator who was assigned to the workplace from another workplace works at the workplace.

Creating a digital model using simulation was possible based on the production line analysis.

3.2 Selection of a suitable simulation tool

The Tecnomatix Plant Simulation was chosen to simulate the production line. As mentioned above, we have three tools available at our workplace: ExtendSIM10, Tecnomatix Plant Simulation, and taraVRbuilder. We decided to use the Tecnomatix Plant Simulation tool from the available tools for two reasons. The first reason, we have experience in creating models in this tool, e.g., versus taraVRbuilder. The second reason is the easy-to-understand available 3D spatial visualisation and animation of material flow during simulation compared to the ExtendSIM10 tool. Based on this 3D spatial animation, it is possible to identify inconsistencies in the material flow quickly.

Tecnomatix Plant Simulation software enables the simulation, visualisation, analysis and optimisation of production systems and logistics processes. Using Plant Simulation enables optimisation of material flow, resource utilisation and logistics for all levels of plant planning, from global facilities and local plants to specific production lines. Tecnomatix Plant Simulation is object-oriented, hierarchical modelling based on dedicated object libraries for fast and efficient discrete and continuous process modelling. This software tool has many built-in tools and graphical outputs to assess production system performance, including automatic bottleneck detection, throughput analysis, etc.

3.3 Simulation model

The following chapter describes how to create a digital model. The simulation model (Figure 3) is created from blocks from the "Material Flow" library, the "Resources" library, the "Information Flow" library, the "User Interface" library and the "Tools" library. Blocks are interconnected using a "Connector".

The first block in the model is the "EventController", which starts, stops, resets and controls the speed of the simulation. It is the starting block without which the model cannot be run.

The input materials in this model are "Source" blocks in 11 pieces (11 input materials), representing the input material warehouse.

The central part of the model is the production line, which contains 15 workplaces. A conveyor belt transports material between individual workplaces comprising the "Conveyor" block. During the production process, the main (input) component is transported along the conveyor belt, where the required operations are gradually performed. Workplaces 1 to 8 and 13 to 14 form the "AssemblyStation" blocks, representing assembly operations (assembly of additional components into the main component). Workplaces 9 to 12 form the "ParallelStation" block. The "ParallelStation" block was used because no other parts are directly assembled at this workplace, but the product is automatically tested. These four workplaces are the same. Workplace 15 also consists of the "AssemblyStation" block, representing product packaging and storage on a pallet. At workplaces 1 to 8 and 13 to 15, a "Workplace" block represents a worker performing his activity. These workers are generated from the "WorkerPool" block and are managed using the "Broker" block. The supply of workplaces occurs along a marked route, represented by the "Track" block. A service vehicle follows this route. This vehicle will load the necessary material from the inbound warehouse. Loading is done using the "Method" block. The block is programmed where and under what conditions the material will be loaded. Next, the vehicle continues along the marked route to workplace No. 1, where it is unloaded using another "Method" block under certain conditions. The vehicle performs these actions at each workplace, and after completion, it returns to the input warehouse, where it starts its cycle again.

The "Chart" block in the model shows the percentage utilisation of individual workplaces. The "ShiftCalendar"

block in the model serves to specify the working time of individual shifts. Workers' breaks during the work shift are also set in this block. The last part of the model is the output warehouse, to which the finished products from the packaging workplace No. 15 are moved using a forklift.

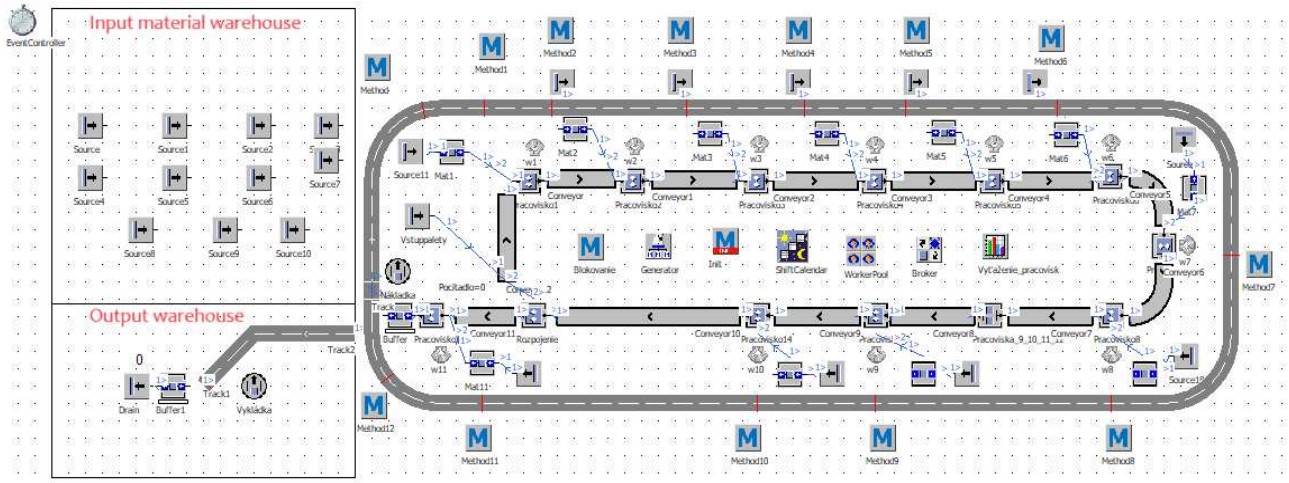

Figure 3 The model print screen

3.4 Verification of simulation model

The verification of the model was carried out by a simulation experiment that simulated the current state. In this experiment, the data obtained by the analysis were used. The experiment was performed for simulated times:

A: 1 shift, 8 hours,
B: 2 shifts, 16 hours,
C: 2 days, 48 hours.

From the simulation experiment for simulated time A, the following results were obtained:

- 96 pieces of finished products (6 pallets) per shift were brought to the output warehouse,
- 97 products were packed at the packaging workplace (Workplace No.15) (6 pallets, 7 pallets contained only 1 box with the finished product), and one product was in the process of being packed,
- the first product was packed and placed on the pallet in less than 45 minutes, and in 1 hour and 53 seconds, 16 products were loaded and taken to the warehouse.

From the simulation experiment for simulated time B, the following results were obtained:

- 192 pieces of finished products were brought to the output warehouse (12 pallets), which represents 96 products per shift,
- 195 products were packed at the packaging workplace (Workplace No.15) (12 pallets, 13 pallets contained only 3 boxes with the finished product), and one product was being packed.

From the simulation experiment for simulated time C, the following results were obtained:

- 384 pieces of finished products were brought to the output warehouse (24 pallets), which again represents 96 products per shift,
- 391 products were packed at the packaging workplace (Workplace No.15) (24 pallets, 25 pallets contained only 7 boxes with the finished product), and one product was again in the packaging process.

Figure 4 shows the utilisation of workplaces. Figure 4 shows in green the utilisation of individual workplaces during two working days (4 working shifts). At workplaces that precede workplaces No. 5 and No. 15, the blocking of the given workplace is shown in yellow. This blocking is caused by work-in-progress products having to wait at workplaces until they are gradually moved to the following workplace, and queues of work-in-progress products are formed. The light blue indicates when the production line is not in production. Production only takes place on the line after the end of the afternoon shift at the start of the morning shift the next day. Breaks during the production process are shown in dark blue (lunch/dinner break).

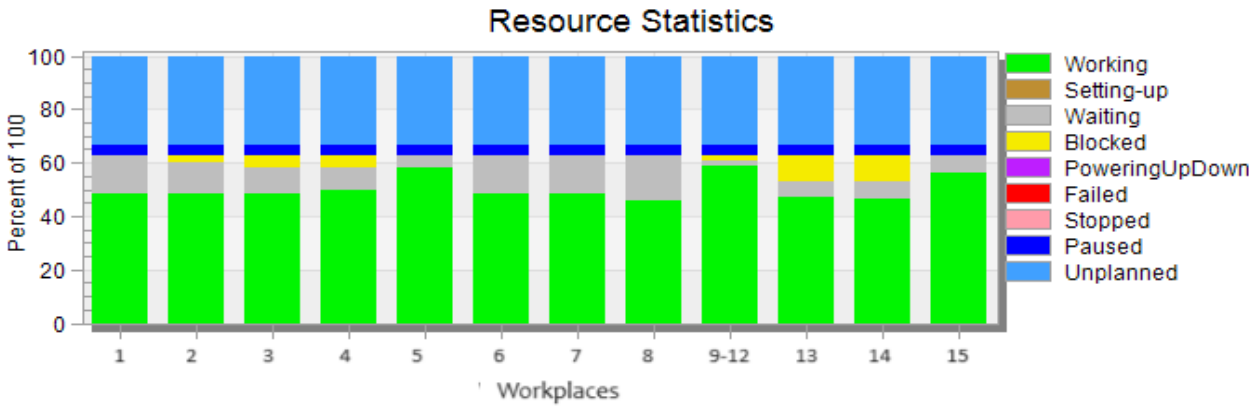

Figure 4 The utilisation of workplaces

The results prove that it is possible to produce 96 products in one working shift on the given line under current conditions. The model is verified, and the values obtained by simulation are identical to those from the analysis.

3.5 Simulation experiments and simulation results

Experiments were performed on the verified model. The main goal of the experiments was to eliminate the blocking of workplaces, to equalise the performance of workplaces and to find out whether it is possible to increase the production of finished products as well. The simulated time in these experiments was two working days, as in experiment C. Experiments were performed:

D: In this experiment, the work cycle time at critical workplace No.5 was adjusted from the original value of 4 minutes to the average time of the previous workplaces, to 3 minutes and 20 seconds. This experiment removed the blocking of workplaces in front of workplace No.5. Blocking workplaces in front of workplace No.15 was not removed. The result of this experiment is the same number of products produced as in the current state.

E: In this experiment, the work cycle time was modified at critical workplace No. 15 from the original value of 4 minutes and 9 seconds to the average time of previous workplaces of 3 minutes and 20 seconds. By adjusting the time, the production of finished products increased from 96 to 103 pieces per shift, i.e., by 7 pieces. The blocking of workplaces in front of workplace No.15 and front of workplace No.5 was not removed.

F: In this experiment, a time adjustment was made at critical workplaces No.5 and No.15 for 3 minutes and 20 seconds. In this experiment, the blocking of workplaces in front of workplaces No.5 and No.15 was removed, and the workload of workplaces was equal, figure 5. The production of finished products increased from 96 to 120 pcs per shift, representing an increase of 24 pcs/shift.

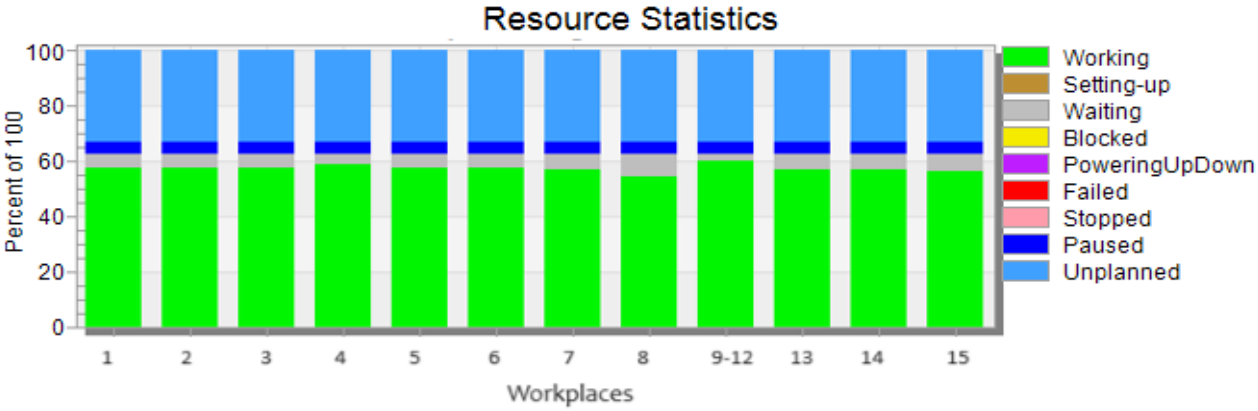

Figure 5 The utilisation of workplaces

Based on experiment F, it was found that on a given line, by reducing the work cycle of selected workplaces, it is possible to remove the blocking of workplaces and increase production by 25%.

3.6 Proposals and recommendations

However, the question arises: How to reduce the time of working cycles in operation?

One of the solutions would be to eliminate the deficiencies identified by the analysis, which are related to the work items and materials used in the workplaces (the

workplaces contained objects that were not necessary for the operation, material and work tools used by workers during production, were not marked and did not have a precisely defined place or arrangement, the operator sometimes has to search for these aids and material and thus the work cycle is extended).

Eliminating these deficiencies is possible by applying the 5S method in workplaces and removing unnecessary items. Most of the material is in crates and pallets of various sizes without marking. Therefore, it would be advisable to place labels with information about the given material (material code, photo of the component, etc.). Precisely designated places for all work aids, tools, and materials used at work would be marked on the worktables, applying a plan for cleaning workplaces and work aids at workplaces at regular intervals, which would impact safety and work productivity.

What increase in production can be achieved in possible demand from this line?

Based on the results of the last experiment, it is possible to increase production by 25%, i.e., 24 pcs per shift, which is 48 products during a two-shift operation. The future decision is whether this increase in production after its efficiency in two-shift operation is sufficient or necessary, e.g., it is within the company's competence to introduce a third direction following its business goals. As for downstream processes, such as the storage distribution of products when production is increased on this line, their assessment was not the subject of the solution in this contribution.

The newly added production volume determines the increase in the degree of employing the production capacity and vice versa [25].

4 Conclusions

It is essential for a manufacturing company that production activities are efficient. So that the production process runs without unnecessary complications, the work cycle should be continuous with as little idle time as possible. This contribution presents a simulation model of a production line where several workplaces were blocked due to the accumulation of material that could not be continuously moved to the following workplace, whose work cycle was not following the previous workplaces. After verifying the model, experiments were carried out on the simulation model, the aim of which was to eliminate the blocking of workplaces, to equalise the workload of workplaces and to find out whether it is possible to increase the production of finished products. Based on the experiments, it was found that in the case of shortening the work cycle at critical workplaces No.5 and No.15 (Experiment F), the accumulation of material at the workplaces that precede the critical workplaces will be removed, the material will continuously move along the production line, the workload of the workplaces will be equalised (Figure 5), downtimes at workplaces will be shortened and partially equalised, thereby increasing the speed of the material flow on the production line. It can be concluded that by shortening the work cycle at workplaces No.5 and No.15, it is possible to make the process more efficient - to equalise the workload of individual workplaces and increase production by 25%, increasing the number of products by 24 pcs/shift.

However, how can we reduce work cycles at critical workplaces? The article presents one of the options, namely the application of the 5S method, which focuses on organising and maintaining a safe, organised, and efficient workplace. Applying this method, whether at selected workplaces or the production line itself, will be beneficial in several areas - reduction of downtime, increase in worker productivity and thus production of the line, and finally, benefits in the field of occupational safety and accident prevention.

Applying the 5S method at workplaces No.5 and No.15 is the first time-saving solution for eliminating the problem related to material flow. Suppose the problem with the material flow persists even after the 5S methods have been applied. In that case, the presented simulation model can be used to verify and evaluate future solutions to the problem.

It is more than likely that in the coming years, there will be an increase in demand for the creation of simulation models of production systems in manufacturing companies that will try to implement the Industry 4.0 strategy and thus increase their competitiveness.

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Improving allocation and layout in production logistics

Martin Straka
Technical University of Košice, Faculty BERG, Institute of Logistics and Transport, Park Komenského 14, 04384 Košice, Slovak Republic, EU, martin.straka@tuke.sk
Peter Kacmary
Technical University of Košice, Faculty BERG, Institute of Logistics and Transport, Park Komenského 14, 04384 Košice, Slovak Republic, EU, peter.kacmary@tuke.sk (corresponding author)
Petr Besta
VŠB - Technical University of Ostrava, 17. listopanu 21/1572, 708 33 Ostrava-Poruba, Czech Republic, EU, petr.besta@vsb.cz

Keywords: allocation and layout, logistics, system, workplaces, production.
Abstract: The article deals with the principled solution of allocation and layout of workplaces in a company producing of variety building components. Allocation and layout are very important areas for ensuring the efficient operation of companies engaged in production as well as in commercial activities. Both allocation and layout solutions have a strategic importance for companies. The investigated company produces construction metal elements as a part of modern construction technologies. The problem is related to the constant improving activities in the company in order to ensure its competitiveness on the market. The production process of construction metal elements consists of workplaces such as cutting, drilling, milling, welding and galvanizing. Workplaces for inspection and loading of finished products are non-production. The solution of the project was aimed at streamlining activities in terms of logistics, material flows as well as in terms of safety.

1 Introduction

While searching for possibilities to increase the production capacities of the manufacturing of building elements in the investigated company, the problem arose how to effectively allocate and place production equipment, warehouses, buffers, to implement transport routes in their production hall where building elements are made. This is also attended by streamlining of the layout of production and interoperation equipment, storage and interstorage areas in the hall to meet technological, safety and capacity requirements.

The procedure for effective solution of allocation and layout consists of the following parts:

- Measurement of premises, production machines, equipment and workplaces.
- Analysis of spatial parameters, possibilities and limitations, machines and equipment, material inputs and outputs of products, material flows in a space, storage possibilities and legislative regulations and standards.
- Design of logistic elements, handling units for the needs of effective activities in production.
- Design of the allocation and layout of production workplaces, machines and equipment for the placement of material at the entrance and during production, the location of the entrance and exit of products for galvanizing and the location of finished products.
- Process-efficient storage of semi-finished products, efficient transport routes within the production hall, creating paths for the safety movement of workers.

2 Literature review

Allocation and layout are an important element for the effective increase of capacities in logistics. The importance of allocation and layout solutions is still the same for any manufacturing company. Many companies approach the solution of allocation and layout systematically, but some make layout more efficient only over time, based on their acquired experience and knowledge. The authors Gabajová, et al. state in their publication that: *"Designing a workplace may be a challenging task. It is important to make sure that the new workplace will prevent unnecessary resource waste, but also create a safe working environment for employees"* [1].

Solution of allocation and also, within certain limitations, layout is a strategic solution that will be implemented in practice for several years. For this reason, the solution must be approached with all seriousness. Allocation is a process that results in the location of the company, warehouse, production, machine and everything that can be allocated on an area or in a specific space [2].

In terms of effective allocation and layout solutions, many methods and procedures can be used. The authors Kronová, et al. used, for example, the Cluster Analysis method for solving layout, which is described in their work [3]. Many authors use computer simulation as an effective means of solving allocation and layout problems [4-8].

According to authors Grznár, et al. *"The one of the most important tasks in designing is detailed design. In this process, the final layout of the elements, together with their demands for space in a common 2D and 3D view, plays a rather complex matter"* [9].

One of the popular methods for solving of the mentioned problem is the CRAFT method (Computerized Relative Allocation of Facilities Technique), which belongs to the group of enumerative methods and gives the optimal solution under defined conditions and constraints. The application of the above method is practically described in the papers [10-13].

There are a number of procedures and methods that can be used to solve a strategic decision of allocation and layout in practice. Therefore, the authors of this paper, when writing the article, limited themselves to the factual side and defining the principle procedures that can be used in general in the subject matter with a practical demonstration of the solution of the specific task.

3 Methodology

Inappropriate allocation and layout of production facilities leads to inefficient logistics, prolonged material flows, longer transport times and an increased need for intermediate warehouses (buffers) for materials, semi-finished and finished products. All this increases the costs associated with the production itself. Allocation and layout efficiency concentrates capacity, material, economic, safety and technological rules in order to minimize subjective approaches in the allocation and layout of workplaces and production facilities.

The solution of the problem applies a project approach with the basic postulates of logistics such as the systems approach, algorithmic thinking, coordination, planning and global optimization, which are contained in the parts forming the methodology:

- The global objective of the project solution is to increase productivity, increase the capacity utilization of equipment, reduce costs and increase safety at work.
- To analyse the actual state of layout of production and interoperation equipment, storage and interstorage areas, including pallets, crates and boxes that form small buffers.
- To define and describe the criteria and principles for the deployment of production and interoperation equipment, storage and interstorage areas and buffers in the production hall, where building elements are made.
- To develop a system for deployment and to propose deployment options taking into account the defined criteria.
- To design logistics elements, handling units for the needs of streamlining operations in production.
- To define the criteria for the selection of the most efficient variant.
- To design an efficient layout of production and interoperation equipment, storage and interstorage areas and buffers by means of a system solution under defined conditions.

4 Result and discussion

Considering the new trends in building industry, the company is focused on the development and production of construction elements that serve both to ensure and to implement construction operations and processes. The priority of the production of construction elements is a sustainable state of effectively spent costs for their production, which is achieved by: streamlining logistics processes, streamlining production processes and using suitable technological equipment and suitable materials as well as their streamlining allocation and layout.

4.1 Presentation of the offered services

Since its establishment, the company has been engaged in the development and production of iron building elements of its own construction. In addition to the production of iron construction elements, the company offers services in the field of processing and implementation of operations related to mechanical production and processing of iron elements such as sheets, "roxors" (reinforcing steel), steel bars with various profiles (I, L, T, U, □, ○, etc.), pipes, prisms, etc. Classification of offered services is followed:

- Cutting - circular saw, automatic band saw, plasma cutter.
- Carving by plasma.
- Drilling - manual, stand drill, automatic.
- Turning.
- Thread milling.
- Welding - electric arc welding in a protective atmosphere of inert gas, spot welding.
- Bending - manual, machine.

4.2 Material flow analysis

There are 6 main material flows in the company (Figure 1), which are characterized by parts with final production or with production for the finalization of building elements.

The material flow analysis shows that material flows through the production hall according to the production technology of each product. In the production of individual products, many of the production operations are identical (cutting, welding, drilling, milling, cleaning and re-drilling after galvanisation, storage, affixing ID labels). The production operations have their own product-specific parameters, which creates considerable variability in terms of equipment set-up and therefore handling time requirements, as well as space requirements for the storage of materials at the start of production, work-in-process materials, semi-finished products, pre-galvanising or galvanising products, and finished products.

Improving allocation and layout in production logistics
Martin Straka, Peter Kacmary, Petr Besta

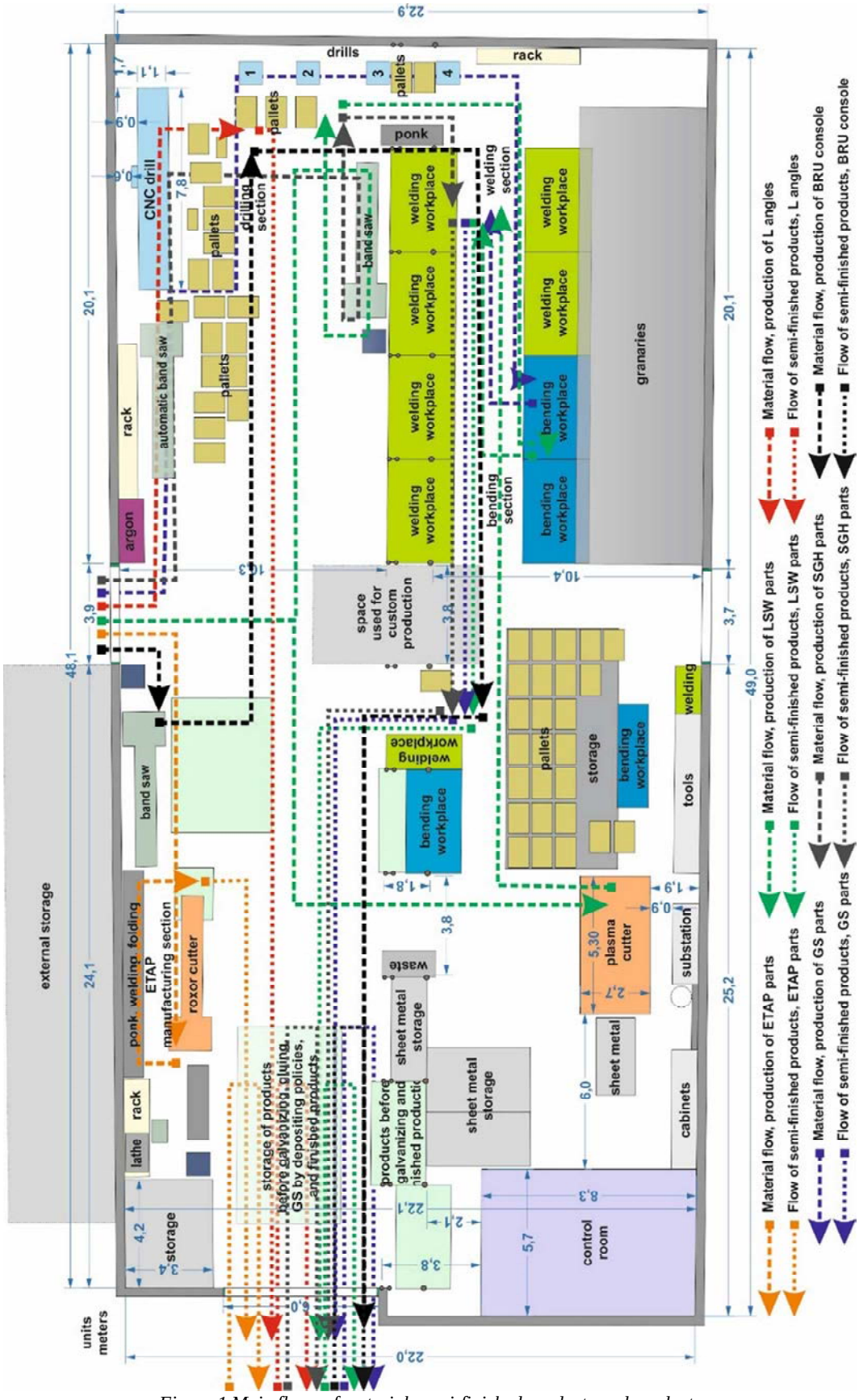

Figure 1 Main flows of material, semi-finished products and products

4.3 Identification of deficiencies in terms of material flows

There are following findings and shortcomings found from the system analysis of the company's activities focused on the allocation and layout of production equipment, materials, semi-finished products, products, waste and material flows:

- The company places its work-in-progress, semi-finished products, products and waste in a large area within the production area (Figure 2).
- Materials in production, semi-finished products, products and waste are stored in various non-standardised "boxes or containers" (paper and polystyrene boxes, plastic crates, iron containers, buckets, wooden boxes, etc.), many of which are not suitable in terms of strength, technically and safety.
- "Containers" with production material, semi-finished products, products and waste are placed on several different types of pallets.
- Downtime on special production equipment, such as automated drilling machines, caused by lack of qualified personnel and production planning.
- Inefficiently used space around the plasma cutter or blocked space around the plasma cutter with various materials and production waste (Figure 3).
- Inefficient use of space for the dispensing and receiving of semi-finished goods and products.
- Crossing of material flows in the production hall.
- Repetitive loading and unloading of semi-finished and finished products in and out of crates, on and off vehicles.

Figure 2 Location of materials, semi-finished products, products and waste in the production hall

Figure 3 Inefficiently used space around the plasma cutter in the production hall

4.4 Design concept for the allocation and layout of the workplace and production facilities

There is advisable to implement the following measures to get the operation of work in the production hall more efficient, which include production and interoperation equipment, storage and interstorage areas, including pallets, crates and boxes and buffers:

- To introduce standardised pallets into the production process.
- To introduce standardized pallet metal boxes and handling units into the production process.
- To introduce standardized pallet racks, stacking of pallets into the production process.
- To introduce storage racks and a shelf stacker for metal sheets (plates) into the production process.
- To streamline the layout of workplaces while respecting technical, technological and safety conditions and constraints.

As many non-standardised crates, boxes, as well as different types of pallets are used in production, it is necessary to introduce standardised pallets, crates and boxes to streamline handling, moving and storage operations.

4.4.1 Storage - handling units

The design of handling units for the storage of materials, semi-finished products, work-in-progress and finished products is based on the existing dimensions of the most common used euro pallets 800 x 1200 mm (Figure 4), in addition to specialised transport units. The height of the euro pallets is set at 144 mm according to STN 26 9110 standard. Its possible load capacity is as follows (according to the mentioned standard):

- 1 000 kg, if the load is arbitrarily distributed on the upper surface of the pallet;
- 1 500 kg, if the load is evenly placed on the top surface of the pallet;

- 2 000 kg, if the load in solid form fits evenly across the entire upper surface of the pallet;
- 4 000 kg an additional load when stacking, if the load is on a pallet adjacent, full flat on a horizontal and rigid surface.

Figure 4 Standard Euro pallet size 800 x 1200 mm

The design of the internal handling unit (hereafter referred to as the box) for use with a standard Euro pallet (but also without it) is 600 x 400 x 200 or 400 mm (l x w x h) for small-sized elements (Figure 5). According to the above pallet and enclosure dimensions, the shape and especially the dimensions of the handling boxes and the arrangement on pallets (Figure 6) are designed to be 1200 mm x 800 mm or 1200 mm x 1000 mm.

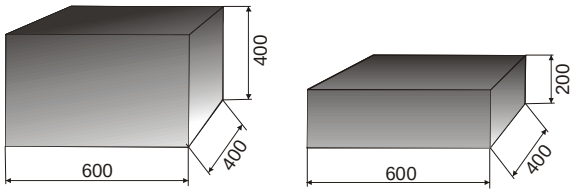

Figure 5 Design of handling boxes and their dimensions

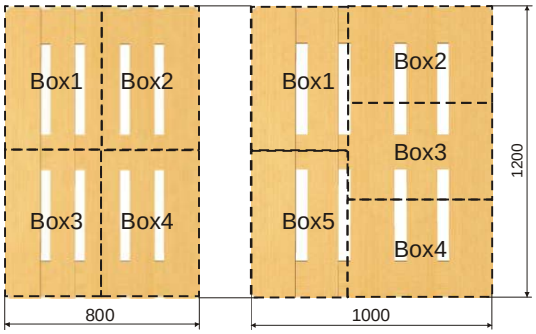

Figure 6 Stacking of proposed boxes on standardised pallets

4.4.2 Allocation and layout of workplaces in compliance with technical, technological and safety conditions and restrictions

The solution and design of the allocation and layout of workplaces, production and interoperation equipment, storage and interstorage areas and buffers must take into account the requirements and restrictions defined by legislation, Slovak technical standards, manufacturing technology and observe safety at work.

The basic constraints and requirements that need to be taken into account when designing the layout are:

- Corridors widths and space around machinery and equipment.
- Width of transition aisles.
- Escape routes.
- Taking into account the sequence of flows of materials, semi-finished and finished products.
- The needs determined by the manufacturing technology.
- Workers requirements.
- Limitations due to the technical condition of the production hall.

The layout designs (Figure 7, Figure 8) of workplaces, production and interoperation equipment, storage and interstorage areas and buffers are based on the following conditions:

- The area around the headquarters (Control and Personnel Centre), has to form a safe zone for the production floor personnel. No forklift or other vehicles shall enter the zone, any other elements restricting movement such as materials, sheets, cuttings, products, etc. cannot be placed in the zone. The zone with the entrance and exit at the Control Centre will form one of the main green escape routes.
- The transition corridor in the middle of the hall must be clear, without serious restrictions. In addition to the material entrances and exits, the corridor also serves as an escape route, located in the centre of the hall between the two opposite doors. It must be kept clear from the point of view of its functionality and to ensure the continuity of material flows, supply and safety.
- The functional form of the products is given by the welding workplaces. Welding processes form the essence of production, it is advisable to centralize them and place them among the columns in the production hall with dimensions per one welding workplace of about 4 x 4 meters. The material flows are concentrated at the welding workplaces, which have their own material inputs and outputs that are dimensionally heterogeneous and as well as they are related to each other in terms of technological processes. For these reasons, it is advisable that the workplaces should have dimensional variability on both, the input and output sides of the workplace.
- The production operations, with their technical support, which form the main content of the production and are carried out regularly, consisting of several types of similar or identical equipment (drilling, cutting), will be cumulated within their sections. This measure can have the synergistic effect of increasing production and the substitutability of production equipment in one section, without the need for unnecessary material transfers.
- Production operations, with their technical support, which do not form the main content of production and are carried out sporadically, will be located at the end or at the wall in the production hall (turning, thread cutting, milling).

- It is necessary to use standardized logistic racks as well as available, non-standard but safe free areas, e.g. on the roof of a tool-warehouse-shelter in the production hall for the needs of efficient location and storage of tools, templates, matrices and other elements for production needs.
- It is necessary to use the storage of the sheets in a specialised self-supporting rack, which is not connected to the supporting columns in the hall (as it was before) for the efficient and safe placement of the steel plates (sheets), for the plasma cutter zone. This solution opens up the possibility of variability for the location of the sheet metal storage in a different location of the production hall columns.

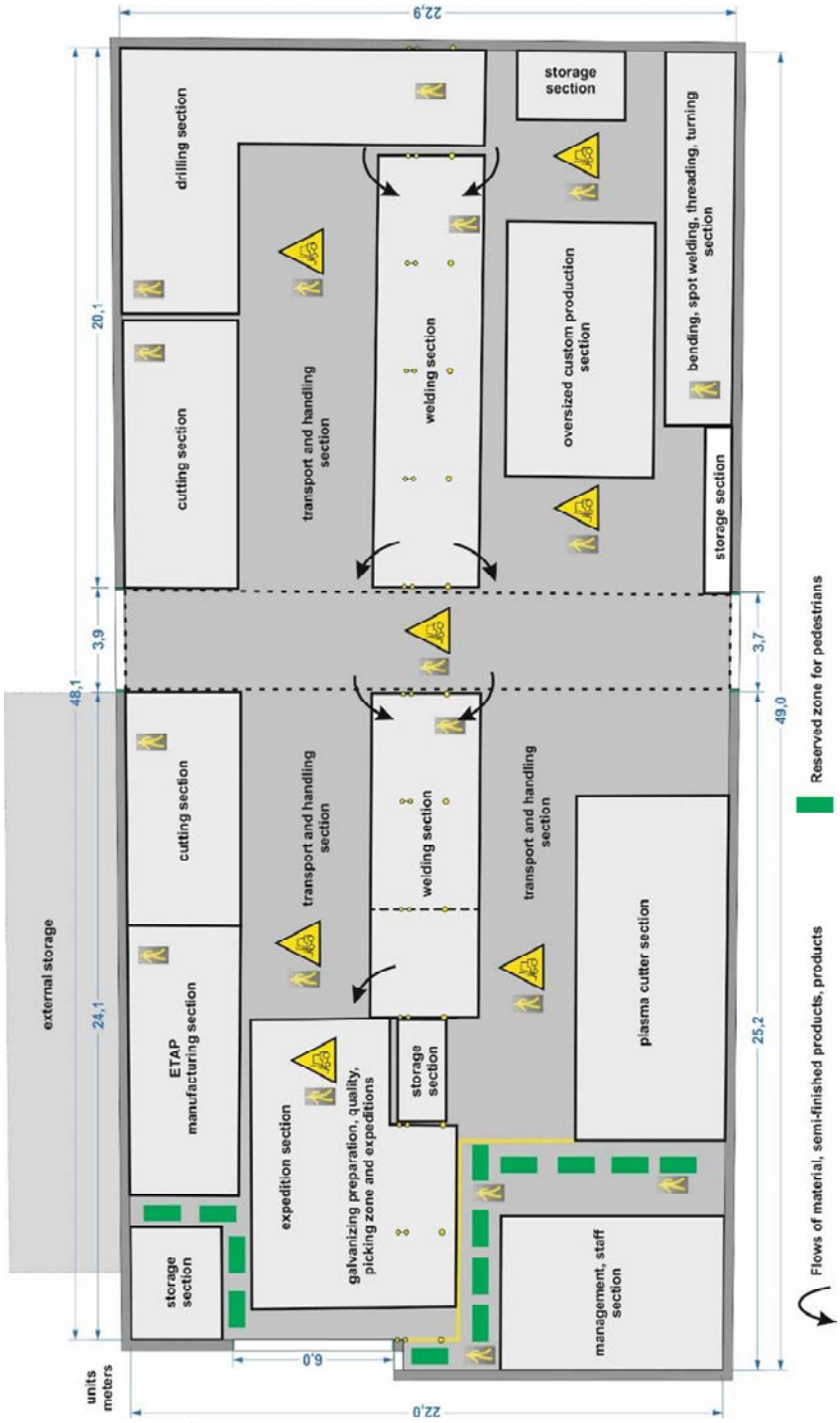

Figure 7 Design of the section layout in the production hall, schematic representation

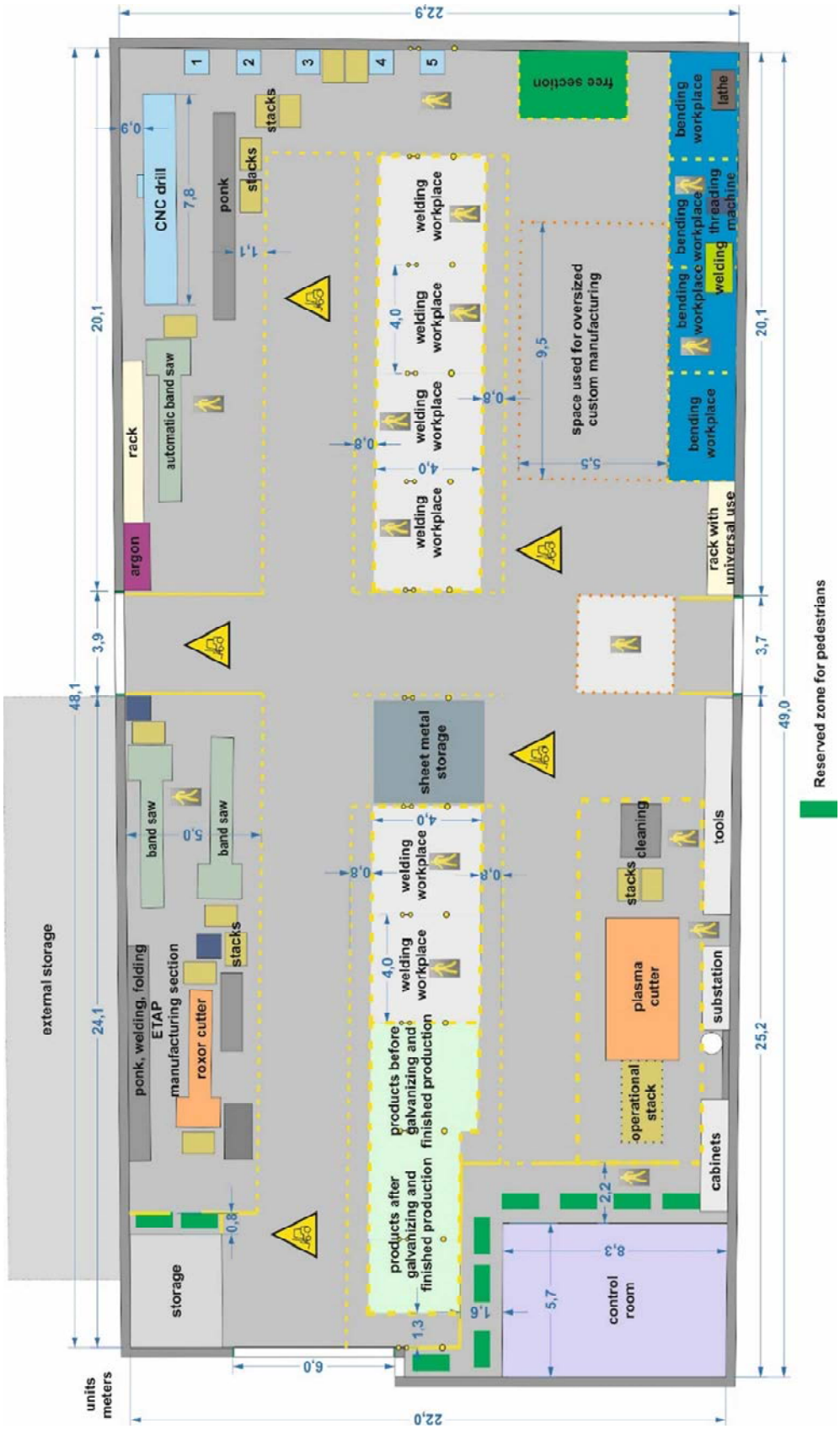

Figure 8 Design of the section layout in the production hall

5 Conclusions

The actual solution of allocation and layout has its own laws, rules, techniques, procedures and methods. In many scientific papers, it is possible to find procedures whose solution is based on common regularities such as the use of computer simulation [14-17], the use of modelling and CAD systems [18-21], the use of multi-criteria decision making [22-25] or other approaches to solve efficient allocation and layout [26-30].

The intention of the allocation and layout solution was to design an efficient layout of metal building elements production workplaces based on their operations and processes as well as logistical patterns for the needs of production efficiency and layout of production and interoperation equipment, storage and interstorage areas and buffers in the production hall, while meeting the defined technical, technological, safety and optimization criteria.

The conceptual solution of allocation and layout for the company engaged in the production of metal building elements brought savings in the form of 30% reduction of crossing material flows, increased safety at work, created workplaces that were arranged according to the procedure defined by the technology of products manufacturing, which ensures smooth material flows, safe zones without mechanization that were defined for workers, standardization was introduced in terms of technical, production and logistic means, small buffers located in a considerable area in the production hall were eliminated and other places without practical use were eliminated too.

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Do I need to use it? Factors influencing the intention to adopt automated parcel lockers as last-mile delivery services
Fara Adura Mohd Yusoff, Fazeeda Mohamad, Puteri Fadzline Muhamad Tamyez, Siti Aisyah Panatik

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Do I need to use it? Factors influencing the intention to adopt automated parcel lockers as last-mile delivery services

Fara Adura Mohd Yusoff
Faculty of Industrial Management, Universiti Malaysia Pahang Al-Sultan Abdullah, Lebuh Persiaran Tun Khalil Yaakob, 26300, Kuantan, Pahang, Malaysia,
Commerce Department, Politeknik Sultan Haji Ahmad Shah, 25350, Kuantan, Pahang, Malaysia, faraadura@gmail.com
Fazeeda Mohamad
Faculty of Industrial Management, Universiti Malaysia Pahang Al-Sultan Abdullah, Lebuh Persiaran Tun Khalil Yaakob, 26300, Kuantan, Pahang, Malaysia, fazeedamohamad@umpsa.edu.my (corresponding author)
Puteri Fadzline Muhamad Tamyez
Faculty of Industrial Management, Universiti Malaysia Pahang Al-Sultan Abdullah, Lebuh Persiaran Tun Khalil Yaakob, 26300, Kuantan, Pahang, Malaysia, fadzline@umpsa.edu.my
Siti Aisyah Panatik
Faculty of Social Science and Humanities, Universiti Teknologi Malaysia, 81310 Skudai, Johor, Malaysia, saisyah@utm.my

Keywords: UTAUT, parcel locker, last-mile delivery, e-commerce, intention.
Abstract: Researchers have been intrigued by parcel lockers for last-mile delivery services, prompting them to investigate the matter more. This study examines factors affecting consumers' intention to use parcel lockers through the Unified Theory of Acceptance and the Use of Technology (UTAUT). This study proposed the mediating role of performance expectancy in the relationship between social influence and effort expectancy with the intention of adopting parcel locker services. An online structured questionnaire was employed and managed to collect data from 444 respondents. The non-probability purposive sampling technique was chosen as the sampling technique, while the SmartPLS version 4.0 analysed research data. The data found that performance expectancy and compatibility over consumers' intention strongly exerted the intention to use parcel lockers. For the mediator factor, the analysis uncovered evidence that performance expectancy can effectively mediate the relationship between social influence, effort expectancy, and intention to adopt parcel lockers. The research demonstrated the significance of the UTAUT model in pinpointing the reason for the parcel locker's adoption intention in Malaysia. The research findings could provide meaningful information to logistics businesses, courier companies, and relevant government bodies to design and implement strategies to enhance the acceptance and usage of parcel lockers as the last delivery option compared to home delivery.

1 Introduction

The sales from global e-commerce achieved an all-time high of 5.2 trillion US dollars in 2021, and it is anticipated that this figure will continue to rise in the years ahead [1]. As a result of the growing popularity of online shopping, last-mile delivery (LMD) has gained prominence and become an integral aspect of the supply chain. One of the potential options to improve the efficiency of LMD and logistics flow is automated parcel lockers [2]. In LMD, automated parcel lockers are a self-service technology (SST) that is a substitute for the more common home delivery practice, allowing onsite and offsite users to conveniently retrieve parcels, consolidate freight, enhancing the use of delivery transport, and shortening delivery routes [3]. As an SST, parcel lockers allow consumers to receive and send their parcels without third-party assistance and might solve the problems posed by home delivery. These benefits have positively increased the use of parcel lockers worldwide. In modern logistics systems, parcel lockers are essential, as they can enhance the efficiency, convenience, and security of the parcel delivery process.

In Malaysia, Pos Malaysia created a parcel locker service in 2016 known as the "EziBox". Meanwhile, a partnership was initiated between Ninja Van and Prasarana Malaysia Berhad, fitted with 86 parcel lockers along Rapid KL Light Rail Transit (LRT) stations from Puchong to Gombak and Ampang. These lockers offer a convenient option for those not at home to receive deliveries and those who prefer to pick up their parcels at the station during their daily commute. In 2021, the Malaysian Communications and Multimedia Commission (MCMC) launched the National Courier Accelerator Package (PAKEJ) to boost postal and courier delivery services. PAKEJ concentrates on introducing more independent pick-up and drop-off (PUDO) activities for local distribution stations. Thus, consumers would be offered more PUDO services, such as a collecting point or parcel storage.

Even though shipping companies are interested in offering parcel locker services, the utilisation rate of parcel lockers is not encouraging. For example, a mere 5.8% of

the parcels received by Ninja Van were delivered to designated collection points [4]. Extensive studies have indicated that the typical consumer remains uncertain about using these types of self-collection services because of innate inertia, concerns about the technology, the lack of convenience, and fear of being exploited if they use a parcel locker [5] and [6]. Past studies illuminated that consumers must embrace the technology instead of strict implementation since forced utilisation could affect attitudes negatively [7]. For the success of parcel locker services, an immediate investigation of consumers' intentions in Malaysia towards using parcel lockers is required. Moreover, although this innovation in LMD is gaining popularity, researchers have largely neglected it [8].

The LMD field gains a substantial depth of knowledge from this research. First, it could expand the existing knowledge regarding the intention to use parcel lockers among consumers, specifically those in Malaysia. Secondly, assessing the part played by performance expectancy as a mediator makes a useful contribution to the body of work connected to last-mile delivery, especially in the context of parcel lockers. Third, the suitability of the UTAUT model for the Malaysian context could be established in this study.

2 Literature review and research hypotheses

2.1 Unified theory of acceptance and use of technology (UTAUT)

In the field of technology acceptance, the Unified Theory of Acceptance and Use of Technology (UTAUT) has been utilised extensively to examine different types of technologies, including learning systems [9], electronic government systems [10], and online banking [11]. The current work evaluates e-commerce-related behavioural intention to adopt one type of self-service technology (parcel lockers) as a last-mile delivery service due to its evident capacity to be utilised in an extensive array of technology acceptance studies. Hence, the study framework is based on the UTAUT presented in Figure 1.

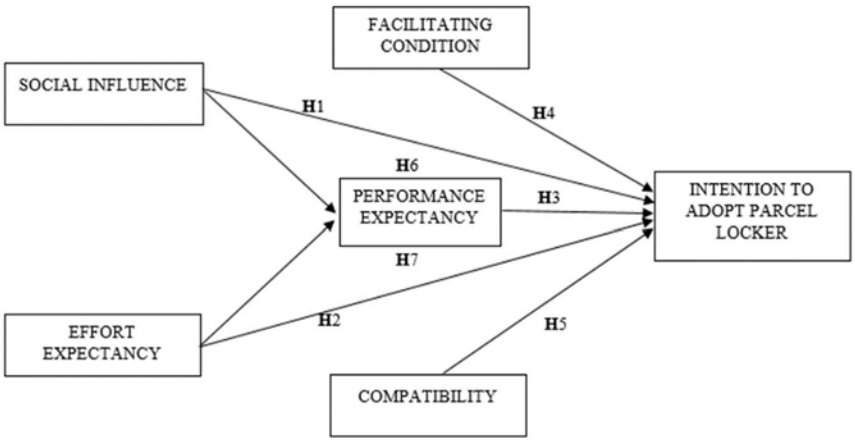

Figure 1 Framework of the study

2.2 Social influence

In the current work, social influence (SI) refers to significant individuals - for example, friends, family members, or those in the community and social circle - who might impact users by supporting the selection of parcel lockers when delivering online purchases. In LMD studies, past studies suggested that social influence assumes an important role in forecasting behavioural intention in utilising autonomous delivery vehicles [12] and parcel lockers [13]. Thus, the first hypothesis is:

H1: Social influence positively influences consumers' intention to adopt parcel locker services.

2.3 Effort expectancy

Effort expectancy is assumed as the belief that consumers held parcel locker delivery and collection is simple; it just requires a smidge of effort. Previous studies have found that perceptions of EE affected the acceptance of various technologies: mobile applications [14], exoskeletons [15] and online pharmacy [16] . In this study, assigning EE as a predictor aids in analysing the belief patterns of consumers in terms of using self-service technology, i.e., parcel lockers. The study formulated the hypothesis:

H2: Effort expectancy positively influences consumers' intention to adopt parcel locker services.

2.4 Performance expectancy

In the present study, performance expectancy (PE) was measured by how much easier people thought sending and receiving packages would be if they used a parcel locker. In earlier LMD studies, PE was also crucial in determining the intention to select autonomous delivery vehicle services [17], express delivery service [18], and green

banking technology [19]. Based on the flexibility of pick-up times and the availability of 24-hour operations, the performance of LMD was expected to improve with parcel lockers. Thus, the second hypothesis is:

H3: Performance expectancy influences consumers' intention to adopt parcel locker services.

2.5 Facilitating conditions

The current study defines facilitating condition (FC) as the availability of an environment and infrastructure that can support the parcel locker application as a last-mile delivery service for online purchases. Other papers have illuminated that FC significantly influence consumers' intention to embrace autonomous delivery vehicle services [17] and online shopping [20]. Thus, based on past finding, the next hypothesis stated that:

H4: Facilitating conditions positively influence consumers' intention to adopt parcel locker services.

2.6 Compatibility

This study proposed compatibility as to whether the LMD innovation - the self-service delivery known as parcel lockers - was compatible with consumers' current values and lifestyles. In the field of innovation acceptance, compatibility has been revealed to be a key element in many areas, such as e-wallets [21], self-collection services [3], and mobile wallets [22]. With the shift in consumers' lifestyles from offline to online shopping, most working consumers are not at home during delivery. Thus, parcel lockers could be another home delivery option corresponding to their requirements, values, and lifestyles. Thus, the following hypothesis was formulated:

H5: Compatibility has a positive influence on the intention of consumers to choose parcel locker services.

2.7 Mediating effect of performance expectancy

Limited research has explored how performance expectancy might mediate between effort expectancy and social influence in parcel lockers utilisation intention. Based on the previous literature, consistent correlations have been exhibited between EE and PE [24,25], SI and PE [25], and PE and intention [18]. Therefore, this study predicted that PE would play the mediator role in 1) linking EE to the intention to adopt parcel lockers and 2) between SI and parcel lockers adoption intention. Thus, H6 and H& are:

H6: Performance expectancy has a mediating effect on the association between social influence and the intention to select parcel lockers.

H7: Performance expectancy has a mediating effect on the association between effort expectancy and the intention to select parcel lockers.

3 Methodology

The completion of the objectives of the study was founded on the quantitative method. The unit of analysis in this study was a person, whereas the response refers to individual responses from e-commerce consumers who had never experienced using parcel locker services. This study conducts survey research by utilising voluntary sampling as a form of non-probability sampling technique. In determining the minimum sample size, G*Power 3.1 performed a priori power analysis [26]. Based on five predictors and to obtain 95% power, medium effect size of 0.15 and a confidence level of 0.05, 138 minimal sample sizes are needed for this study. As [27] suggested, a sample size of 30-500 was considered appropriate. Based on the G* power calculation, 444 responses were collected to test the suggested model. The data was collected during August 2022 through Google form in an online survey form.

The items used in the questionnaire were collected by procuring items from previous studies. The works of [13] were utilised for PE, EE, FC, compatibility, and intention; those of [28] were utilised for SI and FC; those of [21] were utilised for SI; those of [29] were utilised for compatibility; and those of [30] were utilised for intention. The first section inquires about the respondents' background. Meanwhile, section two focused on the factors that led consumers intention to adopt parcel lockers. Thirdly, the intention construct was assessed in the last section. The questionnaire utilised a seven-point Likert scale, from 1 (strongly disagree) to 7 (strongly agree). The study opts for Partial least square-structural equation modelling (PLS-SEM) to analyse the data. This study opted for PLS-SEM due to the capability of SEM to demonstrate statistically significant constructs and stressing predictions when estimating statistical models. Based on the recommendation of [31], a two-step SEM analysis was employed, featuring the measurement and structural models.

4 Result and discussion

4.1 Respondents' demographic

Regarding their demographic profile, from the 444 respondents, the proportion of female respondents (74.1%) outweighed that of male respondents (25.95%). Respondents looked to be largely in the 18-24 age range. In terms of employment, most of the online consumers in this study were students (59.9%), followed by those in full-time employment (32.0%). Meanwhile, most respondents made online purchases monthly (46.4%), but around a quarter of consumers rarely made such purchases (25.7%). Most respondents preferred a home delivery mode for obtaining their products bought online (96.40%). This implies that traditional home delivery remains popular among online consumers in Malaysia.

4.2 Common method bias

As the study only collected single source data, following the advice from [32], the first step was to check common technique bias. Using this method, each variable was regressed on a single common variable. Should the variance inflation factor (VIF) be below 3.3, no bias had been introduced from any single data source. Considering that the VIF in this study was smaller than the threshold value of 3.3, no conflict was seen with common method bias and no evidence of single-source bias in the responses.

4.3 Measurement model analysis

4.3.1 Reliability analysis

Before condusting the analysis, the measurement model has been developed a sshown in Figure 2. The Cronbach's alpha and composite reliability values for each factor are shown in Table 2, demonstrating that every value was higher than the predicted factors' 0.7 cut-off point [33] and thus indicates the high reliability of the measures.

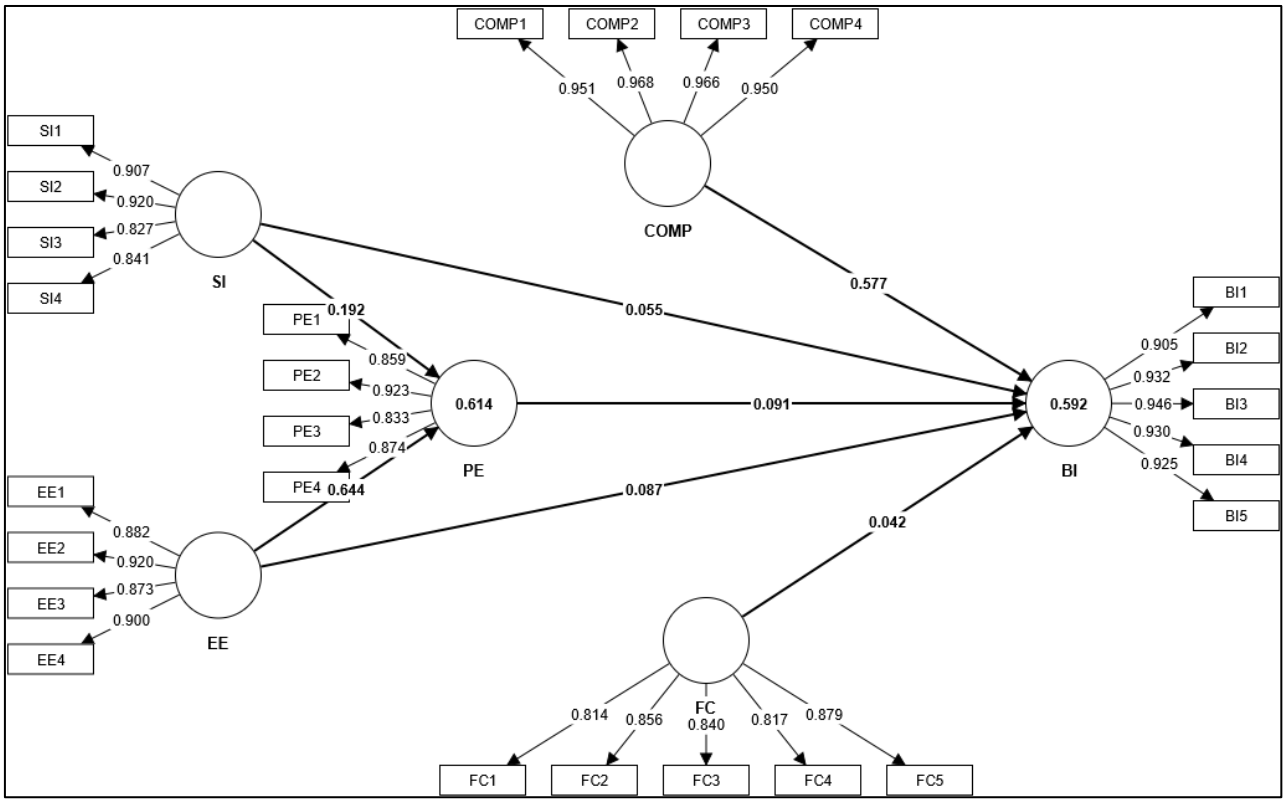

Figure 2 PLS-Path Model

4.3.2 Convergent validity

To determine the eligibility of employing a structural model to test these hypotheses, the measurement model's convergent and discriminant validity had to be determined. The first step was to construct the measurement model was created, as shown in Figure 2. Based on the views of [26], at the point at which the loading and average variance explained (AVE) reach 0.5, convergent validity is deemed to have been obtained. As each standardised loading item was above the 0.7 threshold value for their predicted factor, they were considered significant. Meanwhile, over half of the item variances in each construct differed statistically significantly from the others because the latent constructs' extracted average variances (AVE) ranged between 0.708 and 0.919, above the optional 0.5 cut-off value [33]. Since all the values were above the minimum level recommended in the literature, the conditions of convergent validity were met in this study. The findings of the measurement model have been compiled in Table 1.

Table 1 Convergent validity

Construct	Item Code	Outer Loading	Cronbach's alpha	CR	AVE
Behaviour Intention	BI1	0.905	0.960	0.969	0.861
	BI2	0.932			
	BI3	0.946			

Construct	Item Code	Outer Loading	Cronbach's alpha	CR	AVE
	B14	0.930			
	BI5	0.925			
Compatibility	COMP1	0.951	0.971	0.978	0.919
	COMP2	0.968			
	COMP3	0.966			
	COMP4	0.950			
Effort Expectancy	EE1	0.882	0.916	0.941	0.799
	EE2	0.920			
	EE3	0.873			
	EE4	0.900			
Facilitating Condition	FC1	0.814	0.898	0.924	0.708
	FC2	0.856			
	FC3	0.840			
	FC4	0.817			
	FC5	0.879			
Performance Expectancy	PE1	0.859	0.895	0.927	0.762
	PE2	0.923			
	PE3	0.832			
	PE4	0.875			
Social Influence	SI1	0.900	0.899	0.929	0.766
	SI2	0.916			
	SI3	0.834			
	SI4	0.847			

4.3.3 Discriminant validity

Discriminant validity must be determined when convergent validity has been demonstrated. Discriminant validity was achieved when the heterotrait-monotrait ratio (HTMT) value was less than 0.90 [34]. Based on Table 2, all the HTMT values met the specified conditions, proving that the discriminant validity had not been affected.

Table 2 Discriminant validity: Heterotrait-Monotrait Ratio Statistics (HTMT)

	BI	COMP	EE	FC	PE	SI
BI						
COMP	0.780					
EE	0.660	0.740				
FC	0.513	0.573	0.615			
PE	0.620	0.673	0.844	0.546		
SI	0.601	0.683	0.715	0.723	0.670	

4.4 Structural model analysis

Based on the suggestion by [35], standard beta (b) values, and t-values obtained through bootstrapping with a resample numbering 5,000 were analysed to measure the structural model. As indicated in *Table 3*, performance expectancy and compatibility were significantly linked to the intention for parcel lockers adoption, with each variable having values of (b=0.091, t= 1.884: LL= 0.014, UL 0.174) and (b=0.577, t =10.091: LL= 0.481), respectively. Therefore, H4 and H5 were supported. Conversely, no support was demonstrated for social influence (b=0.055, t = 1.057), effort expectancy (b =0.087, t = 1.399), or facilitating conditions (b=0.042, t= 0.868). Regarding the mediation analysis, both H6 and H7 were supported. By following a suggestion by [36], the significant relationship that effort expectancy had intending to adopt when performance expectancy was the mediator is shown in Table 3 (SI → PE → INT; b = 0.017, t= 1.467) and (EE → PE → INT; b = 0.059, t=1.813). Concerning f^2, the investigation discovered that f^2 for COMP → INT = 0.358 and PE → INT= 0.008, indicating that the effect size of each hypothesis is either small or large.

Regarding the variation in intention, 52.9% might be explained by the exogenous variables, as shown by the value of the coefficient of determination (R2) being 0.529. [37] recommended using PLS predictive to improve predictive capability in response to the current critique of the blindfolding practice. Most RMSE values for PLS-SEM were below those of the LM for the dependent BI constructs, as Table 4 shows. The study concluded that the model has medium predictive power. Meanwhile, some indicators recorded lower RMSE values for predicting the

errors of PLS-SEM than the LM for the PE construct, indicating the low predictive power of the model.

Table 3 Summary of hypotheses testing

Hypotheses	Path	Beta	Standard Error	t Value	Confidence Interval 5.00%	Confidence Interval 95.00%	Decision
Direct effects							
H1	SI -> BI	0.055	0.052	1.057	-0.032	0.139	Not supported
H2	EE -> BI	0.087	0.062	1.399	-0.017	0.188	Not supported
H3	PE -> BI	0.091	0.048	1.884	0.014	0.174	Supported
H4	FC -> BI	0.042	0.048	0.868	-0.041	0.116	Not supported
H5	COMP -> BI	0.577	0.057	10.091	0.48	0.670	Supported
Indirect effects							
H6	SI -> PE -> BI	0.017	0.011	1.647	0.004	0.039	Supported
H7	EE -> PE -> BI	0.059	0.032	1.813	0.01	0.117	Supported

Note: $p \leq 0.05$ (1-tailed test). LL, lower limit; UL, upper limit at 95% and 99% confidence interval

Table 4 PLS predict

Items	Q^2 predict	PLS-SEM_RMSE	LM_RMSE
BI1	0.462	0.907	0.931
BI2	0.502	0.842	0.866
BI3	0.528	0.917	0.939
BI4	0.496	0.949	0.965
BI5	0.492	0.977	0.991
PE1	0.411	0.937	0.933
PE2	0.549	0.838	0.810
PE3	0.382	0.977	0.992
PE4	0.498	0.894	0.908

5 Discussion and conclusion

These results could become the basis for further studies on using the UTAUT model in the context of parcel lockers. Each predictor variable's standardised beta coefficient was checked to inspect the impacts on the endogenous variable of the exogenous variables, as the research hypotheses outlined. Nevertheless, no contribution was made to the intention to adopt parcel locker services by SI, EE, or FC.

As illustrated in Table 3, three hypotheses were rejected (H1, H2, and H4), and four hypotheses were validated (H3, H5, H6, and H7). Of the UTAUT predictors, performance expectancy (H3) was the most significant factor for the subjects studied. The current findings correspond to those obtained in different studies on LMD, which have illustrated how performance expectancy significantly impacts the intention to utilise various LMD-related technologies [18,19]. This shows that Malaysian consumers' intention to adopt parcel locker services was strongly founded on factors highlighting functional advantages (performance expectancy).

Except for that UTAUT construct, compatibility was also found to significantly influence consumers' intention to adopt parcel lockers. These outcomes resemble those obtained by other researchers investigating technology adoption in e-wallets [22] and mobile banking [38]. In a trend predicted to be ongoing, the typical modern consumer has generally become familiar with online purchases. Furthermore, most consumers, especially those in cities, work and not at home for parcel delivery. Therefore, a parcel locker can be considered a delivery method compatible with modern consumers' lifestyles.

Social influence was found not to significantly influence consumers' intention to adopt parcel locker services, so H1 was not supported. Alignment was identified between this outcome and those of previous studies to have employed the UTAUT model, in which social influence was revealed as less relevant [14]. This could have been because the current research was conducted from the individual perspectives of consumers without experience using parcel lockers. It is highly likely that most of the respondents had a social circle or lived in a community that did not use parcel lockers. Therefore, social influence has no significant influence on the intention to use parcel lockers.

This study also shows that the exogenous variables of EE and FC did not significantly affect behaviour intention; hence, H2 and H4 were not supported. The outcome demonstrates inconsistency with certain previous works, which have illustrated the important influence of the EE factor on the intention to utilise technology [39]. Given that the parcel locker is a new method of delivery in comparison to standard home delivery, this finding was surprising, even though it was consistent with those of several other studies [40] and [21]. The facilitating conditions findings were consistent with those of other researchers [41] and [42] who found this was not a significant factor affecting individuals' intentions to utilise

technology. In this study context, the sample consisted of non-users of parcel locker services, so they may have lacked the understanding and skills necessary to facilitate parcel lockers in terms of the organisational and technological infrastructure.

The study suggested that PE was a mediator between the relationship of SI and adoption intention and between EE and intention to adopt. The result validated the mediating influence of PE on the connection between H6 and H7. These results demonstrated the significance of performance expectations in shaping consumers' intention to utilise automated parcel lockers. The analysis of Hypothesis 6 revealed that performance expectancy would likely decline when individuals in a respondent's circle, such as their friends or family, did not use parcel lockers and thought the respondent should not use such services either, which appeared to affect the respondent's decision about whether or not to use the service themselves. The acceptance of H5 means that when consumers possess a high level of performance expectancy and are informed of the superiority of automated parcel locker services, they are more inclined to employ automated parcel lockers, even if they need to make additional efforts to receive their parcel compared to when arranging home delivery.

In conclusion, performance expectancy is a key influence on the intention to use parcel locker services. Therefore, delivery companies offering parcel locker delivery services should prioritise enhancing the functionality and performance of parcel lockers to encourage more consumer interest and adoption in the future. Apart from providing effective parcel locker services, delivery companies and relevant agencies should also disseminate details about the advantages and performance of parcel lockers, such as service efficiency, accuracy and reliability, convenience, and environmental considerations. As parcel lockers are useful and easier to collect and post, it is paramount to highlight these features among consumers to motivate them to move from the classic delivery modes to automated parcel lockers. Clear communication about the advantages and performance of parcel lockers can influence positive performance expectations, consequently increasing their intention to adopt parcel lockers services.

6 Theoretical and practical contribution

6.1 Theoretical contributions

The theoretical ramifications of the findings deliver a momentous contribution to the current knowledge and illustrate the significant predictors of consumers' behavioural intention to adopt self-service technology like automated parcel lockers. An important feature is a confirmation that the main influence on the intention of consumers to adopt parcel locker services is performance expectation. Using the UTAUT model and examining the mediating influences of performance expectancy yielded useful insights. In addition, using a quantitative methodology and PLS-SEM brought validity to the study's findings, which are a valuable contribution to this type of research in the context of a developing country.

6.2 Practical implications

To ensure the outstanding performance of parcel lockers, courier managers should devise various techniques. This should lead to improved consumer expectations of the performance of parcel lockers and an increase in positive recommendations from those in their social circle. Once they recognise the good performance of parcel locker services, consumers will not hesitate to use such services even if they know they must participate and exert more effort to complete the delivery process. A further recommendation is to exploit media platforms - such as short message services (SMS), emailing, and social networks like Facebook - as these can be useful in fostering electronic and effective word of mouth. This would improve the function of future parcel locker consumer intention and adoption rates.

7 Limitations and suggestions for future research

The current research outcomes highlight how useful the UTAUT model could be in conducting analyses of Malaysian customers' perceptions of self-service parcel lockers. Regardless of the significance of the study's findings, some limitations may determine future research paths. Firstly, the sample could be expanded to allow for coverage of a broader geographical area of Malaysia, such as other rural areas, instead of focusing solely on an urban area. Secondly, this study utilised the UTAUT paradigm to examine potential drivers of intention to use. Therefore, the body of knowledge could be augmented by investigating online shoppers' motivations for using automated parcel lockers from various theoretical perspectives.

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Supplier relationship management and its impacts on purchasing performance in aircraft maintenance, repair, and overhaul in Thailand

Peter Madzik
Technical University in Liberec, Faculty of Economic, Voronezska 13, 460 01 Liberec, Czech Republic, EU, peter.madzik@tul.cz
Noppadol Suwannasap
Rajamangala University of Technology Thanyaburi, 39 Moo.1, Klonghok, Klong-luang, Pathumthani, 12110, Thailand, noppadol_s@rmutt.ac.th (corresponding author)

Keywords: supplier relationship management, purchasing performance, aircraft maintenance, MRO, Delphi.
Abstract: Supplier Relationship Management (SRM) has been recognized to play an important role in improving purchasing performance. However, there is no evidence yet to prove this application in the aircraft maintenance, repair, and overhaul (MRO) industry in Thailand. This paper studied SRM which are arm's-length SRM and cooperative SRM practices, and their impacts on purchasing performance in the aircraft MRO industry of Thailand by using Delphi Technique. Data are collected from in-depth interviews, and by means of a questionnaire. Sample group of this research are 20 specialists who involved with purchasing processes in aircraft MRO. The results show that cooperative SRM improves purchasing performance in all aspects, while arm's-length SRM only improves purchasing performance in reducing sales price.

1 Introduction

The COVID–19 pandemic hampered the economic growth of almost every country and resulted in closure of many airline companies. In 2020, aviation industry revenues totalled $328 billion, around 40 percent of the previous year [1]. With more than half of the global fleet on ground in 2020 and lower utilization of the remaining aircraft, airlines deferred as much maintenance as possible to preserve the company cash flow [2]. According to the Oliver Wyman forecast in 2020, the MRO revenues across the aviation industry declined 41 percent if compared with 2019. However, as per a report, MRO demand is expected to grow 50 percent between 2021 and 2024 and increase of over $30 billion, as fleet size and utilization gradually get back to pre-COVID level [3]. Heath Patrick, Steven Lien and Jim Currier, leaders from Honeywell Aero Space explained that the aviation industry need to focus on cost structure, reliability of aircraft and equipment, support staff and crews to recover post pandemic [4]. To reduce cost and increase the reliability of aircraft, MRO purchasing will be an important tool in this situation as it will support the flow of MRO inventory and aircraft maintenance efficiency.

SRM is a purchasing strategy which has been recognized for reducing purchasing costs, purchasing errors, the process of inventory management, while improving product quality and the accuracy of product delivery [5]. Through research, such recognition has been proven in manufacturing, retail, wholesale, and distribution sectors. However, when employing SRM, there is not much evidence proving improvement to the purchasing performances of other industries, including aircraft MRO industry. When purchasing aircraft spare parts, the aircraft MRO industry in Thailand has some drawbacks in comparison to neighbouring countries, such as Malaysia and Singapore. Purchasing in the aircraft MRO industry of Thailand still focuses on supporting operations, rather than being a core strategy of the organisation. As a result, it is impossible to optimise purchasing performance [6]. Due to the recovery of aviation industry, the demand in aircraft maintenance and aircraft spare parts requirement increases. Delivery time and inventory management have become main activities in this situation, as well as cost control. Therefore, finding an effective purchasing strategy for aircraft MRO has become essential and consequently SRM in aircraft MRO industry received more attention than in previous.

This research is qualitative research by using Delphi research method, which is suitable to collect expert opinions in a small group and allow experts to re-consider their opinions in the topics that they answer. Data were collected from purchasing managers and senior purchasing officers in the airline MRO division or aircraft MRO companies in Thailand. There were 10 organisations and 2 people from each were interviewed. The objective is to study SRM activities, the implementation of SRM, and its effects on purchasing performance. Results are used to build a conceptual model of SRM types that suitable to the aircraft MRO industry.

2 Literature review

In recent times, the theories, conceptual frameworks, and researches about SRM have received a lot of attention. Most researches focused on the characteristics of different SRM types and the impacts of SRM on organizational performances in terms of costing and production efficiency. However, this research studied the impacts of SRM on purchasing performance. The literature review focuses on SRM factors in selecting SRM types, different

SRM types, purchasing, purchasing performance and variables used in the conceptual model.

2.1 Supplier Relationship Management (SRM)

SRM is an ongoing process, which aims to build a harmonious purchasing-supplier relationship, through which both parties work together to streamline and make the purchasing and supply chain processes more efficient in long term [7,8]. Different ways to categorize the purchasing-supplier relationship have been presented by academics and researchers, however, they are generally categorized into 4 ideals.

The first one is an ***arm's-length relationship***, which occurs only when a purchase occurs. It is a short-term purchasing-supplier relationship which mainly focuses on reducing costs, and there is no collaboration or two-way exchange of information [9-13]. The second is represented by a ***participating relationship*** between the supplier and purchasing. Both organisations coordinate to solve problems, but on a limited basis. The partnership usually has short-term aims, which mostly targets on cost-reduction and prompt product delivery [9,11,13]. The third purchasing-supplier relationship is a ***collaborative relationship*** in which purchasing and sales cooperate in strategy planning, operational planning and problem solving. This relationship has long-term aims and focuses on cost-reduction and improvement to the efficiencies of both organizations [9,10,12,13]. The last is ***strategic alliances*** that are represented by collaborative purchasing-supplier relationships, with no 'end-date'. Both parties are committed to working closely together, in joint: product design, strategy planning, problem solving and ventures. They aim for complete cost reduction and improved performance [10,11,13,14].

2.2 Factors which affect the decisions in choosing SRM types

SRM is categorized into many types, according to the characteristics and activities. Therefore, implementation of the right SRM type to the industry is essential [9]. From the literature review and related researches, factors which affect the decisions for choosing SRM types can be summarized into three main factors.

The first factor is product purchased. ***Types of products purchased*** has direct impacts on SRM types [15]. Product quality and unique features or product types are important factors to consider too when choosing SRM types [16]. Product price and product value are also important when selecting SRM types to implement [17,18]. ***Types of purchasing policies*** is the second factor affecting the decisions in choosing SRM types. The main important purchasing policies according to the literature review are purchasing policy according to supplier ability, purchasing policy according to purchasing costs, and purchasing policy according to purchasing contract period [16,19-21]. The different purchasing policies are suitable to the different types of SRM. The last factor affecting the decisions in choosing SRM type is the ***collaboration degree with supplier***. There are two important factors relating to collaboration degree with supplier, which are the degree of collaboration according to the activities that supplier and buyer doing together [15], and the degree of collaboration according to information exchange or information sharing [16].

2.3 Purchasing and purchasing performance

Many companies have turned their attention to purchasing because it greatly influences cost reduction and enhances business competitiveness. Nowadays, purchasing concepts differ from purchasing concepts in the past. Traditional purchasing concepts focused on 'low price and on-time delivery. However, these contained additional hidden operational costs [22]. Purchasers nowadays focus on complete cost reduction, value-added service, the ability to meet customer needs and long-term supplier relationships [23]. No matter which concepts are used, an organization still needs efficient purchasing, and that efficiency must also be measurable. According to literature reviewed, purchasing key performance indicators can be divided into 4 categories, which comprise: cost effectiveness, quality performance, on-time delivery, and quantity accuracy [24].

Cost effectiveness is the most important key performance indicator for measuring purchasing performance. Cost effectiveness focus on unit price reduction, ordering cost, inventory cost and transportation cost. ***Quality performance*** focus on the quality of product purchased and the quality of supplier. It is measured by the level of product purchased that not meeting the quality requirement, the purchasing satisfaction level of the supplier's performance in responsibility and delivery. ***On time delivery*** measured by lead time requirement, the number of on time delivery, delay of production process due to late delivery of product or material. The last key performance indicator is ***quantity accuracy*** which measured by the number of deliveries with the incorrect quantity and defects, and the deficit or surplus of inventory caused by the purchasing and scheduling departments themselves.

2.4 Research gap

According to the relevant literature, there are various study areas for SRM research. Some focus on SRM's type and activities in the different environments, some focus on the impacts of SRM on interested factors, and while some focus on the factors that affect SRM.

In this research, we focus on 3 important areas in SRM, which are types of SRM used in aircraft MRO industry, factors that influence selecting SRM types and the effects of SRM on purchasing performance. Hines [9] explained that different SRM types are suitable for different business situations. To implement the right type of SRM, the company needs to understand their requirements and limitations, including examining the factors that related to

selecting SRM types in each business situation. SRM has been proved to have significant impact on organization performance in many areas, such as cost reduction, operation and production performance, distribution, inventory control and purchasing performance. The different SRM types will bring different benefits in business performance. The study about different types of SRM and their effects on different purchasing performance indicators will also help organization to design and implement the correct SRM type to suit their requirement and situation, especially in post Covid-19 recovery situation for aircraft MRO industry.

3 Methodology

This research is qualitative research using Delphi research method (Figure 1), which has been proven to be a reliable measurement instrument in developing new concepts and setting direction of future-orientated research [25]. Data were collected from in-depth interviews, and by means of a questionnaire. These were conducted with purchasing managers and senior purchasing officers in the airline MRO division, or aircraft MRO companies in Thailand. Two specialists were selected from each of 10 organisations. The sample size was 20, which is the quantity required to achieve a reliability success rate of 90-95% [26]. In Delphi exercise, a minimum of 12 respondents is generally considered to be sufficient to enable consensus to be achieved [27]. Each organisation was chosen by using simple random sampling, from a population of 40 organisations [28]. Data collection was divided into two cycles to compare and confirm the opinion of experts for each question. In the first cycle, open-ended questions were used in in-depth interviews, which were also semi-structured interviews. In the second cycle, a rating scale questionnaire and structured interviews were both conducted. Both were pre-planned interviews [29], which covered the topics relating to SRM types: factors which affect the decision-making in choosing SRM types, purchasing performance measurement, and the impacts of SRM on purchasing performance.

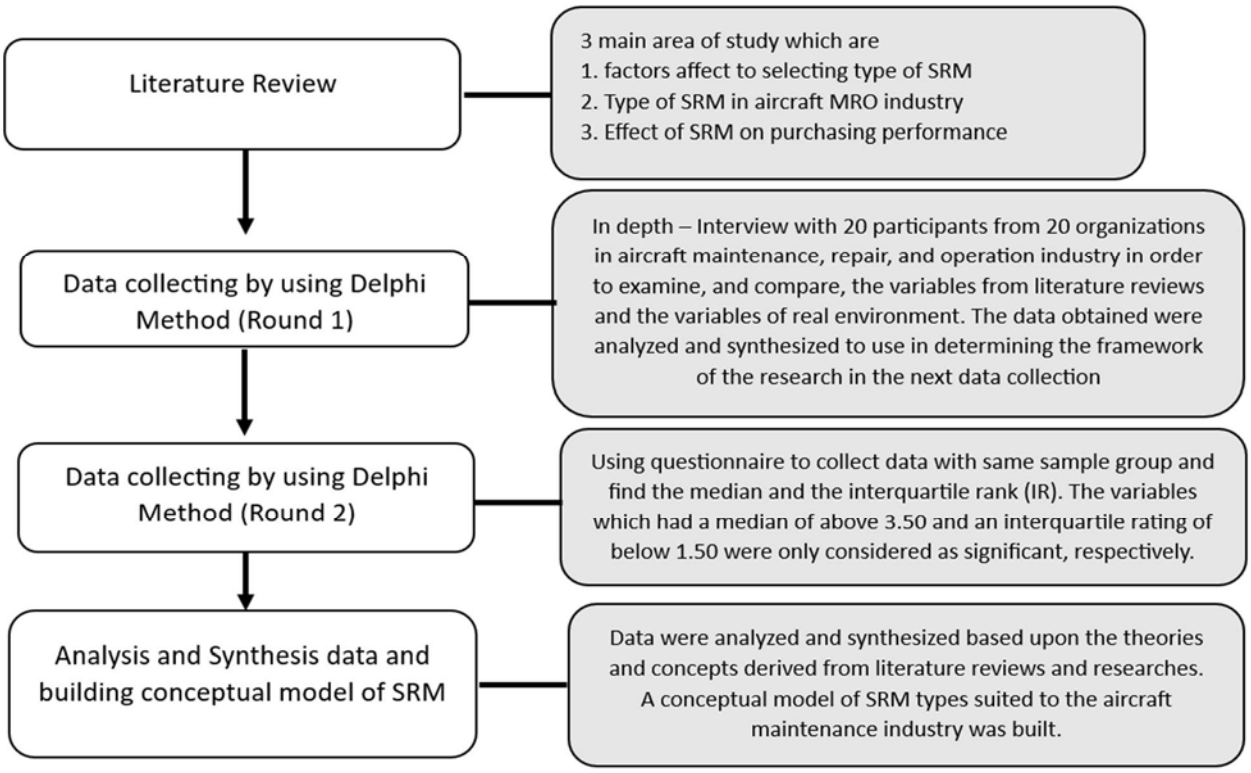

Figure 1 Flow diagram illustrating the method of this research

4 Results

The results will be presented in two parts. The first part showed the results obtained from the first cycle of data collection, and the second part is the results from the second cycle of data collection. Details are as follows:

4.1 Results from the first cycle of data collection

The results obtained from the open-ended questions in the interviews with specialists showed that there are two main types of SRM used in the aircraft MRO divisions of airlines or aircraft MRO companies: arm's-length SRM and cooperative SRM. The factors affecting the decisions for choosing each SRM can be summarised into four types of ideals: (1) types of goods/parts purchased, (2) supplier

type, (3) purchasing policies, and (4) collaboration degree between suppliers and purchasing. For the variables related to the SRM activities, the data from in-depth interviews showed that there are three main categories: (1) purchasing activities, (2) information-sharing related activities, and (3) other activities in managing product quality, managing inventories, and using supplier technologies and knowledge. For the impacts of SRM on purchasing performance, most interviewees reported that SRM will affect purchasing performance, in four areas: (1) purchasing costs, (2) purchase volumes, (3) delivery lead times, and (4) supplier performance.

4.2 Results from the second cycle of data collection

Data from the in-depth interviews conducted were used to develop a rating scale questionnaire to collect data for forming a structured interviews. The questionnaire was given to the same sample to verify the importance of the variables to be used when developing a SRM conceptual model that suit the aircraft MRO industry in Thailand. The results of the second cycle of data collection can be summed up in the variables used, as shown in figure 2-19. The result of factors which affect decision in choosing SRM types is shown as radar chart for each sub-factors as Figure 2 - Figure 5.

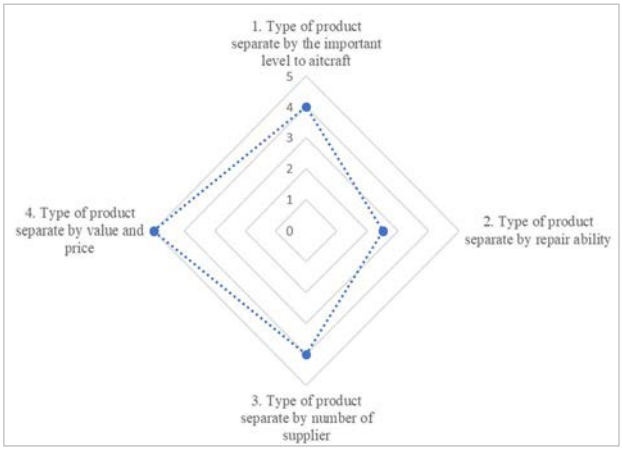

Figure 2 Median score for type of product which effect to selecting SRM type

The results showed that specialists emphasised on almost all factors, excluding product types separated by repairability whose median score is 2.5. Most specialists explained that types of goods can be divided into 'Consumable products' and 'Reparable products' and all SRM types are used for both consumable and reparable products. The results also showed the factors of goods type according to value and price is the most important. Cooperative SRM is suitable to employ for goods which have high value and only provided by a limited number of suppliers. In contrast, arm's-length SRM is suitable to goods which have low value yet provided by multiple suppliers. For product types that separated by its importance level for aircraft, specialists suggested using cooperative SRM with the more important parts and arm's-length SRM with the lesser important parts.

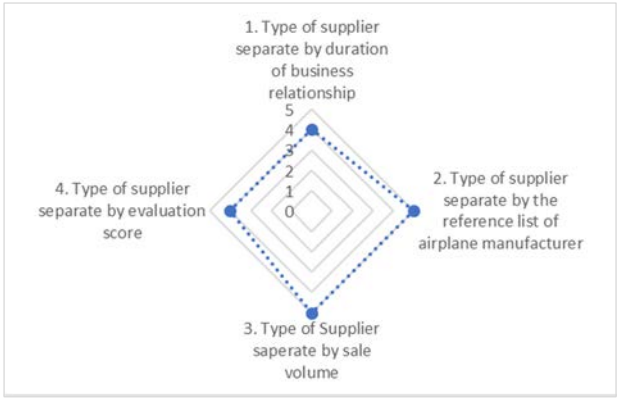

Figure 3 Median score for type of supplier which effect to selecting SRM type

Supplier type directly affect the decision-making in choosing SRM types. Specialists emphasized the median score of all factors under this category are over than 3.5. When studying the details, cooperative SRM is found to be used for suppliers who have had longer business relationships and high trading values, and suppliers who scored high in supplier evaluation. In contrast, arm's-length SRM is used with suppliers who have had a short business relationship and have low trading values, and suppliers who passed the supplier evaluation at standard level. The results also showed that cooperative SRM is used with suppliers who are on the reference list of aircraft manufacturers, while arm's-length SRM is used with suppliers who are not.

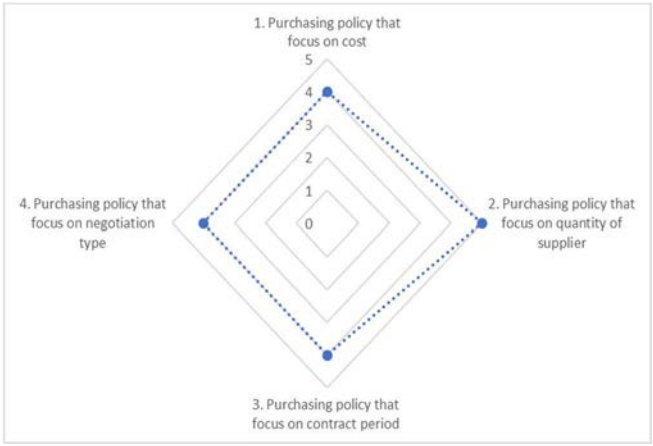

Figure 4 Median score for type of purchasing policies which effect to selecting SRM type

Specialists emphasized all factors related to purchasing policies, the median score of all are over than 3.5. Purchasing policy that focus on quantity of supplier get the highest score from specialists. Cooperative SRM is used

for a single supplier policy, while arm's-length SRM is used in multiple supplier purchasing policy. Cooperative SRM suits to use in purchasing policies which focus on complete purchasing costs, long-term contracts, and win-win negotiations. On the other hand, arm's-length SRM suits for purchasing policies which focus on price, no contract terms, and win-lose negotiations.

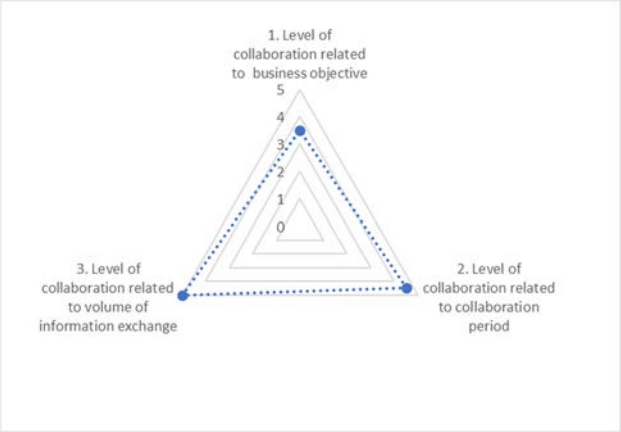

Figure 5 Median score for type of level of collaboration which effect to selecting SRM type

The collaboration degree between purchasing and supplier focuses on the areas of information-sharing, time-line of collaboration and business purpose, the median score for all area are over than 3.5. Cooperative SRM is suitable to employ with the suppliers who have greater level of information-sharing, longer perceived duration of collaboration and financial recuperation, and ventures into other areas. The interquartile range for every factor are equal to 1, therefore, it is considered as significant, respectively.

The result of important activities in both SRM types is shown as radar charts for sub-factors as Figure 6 - Figure 11.

Figure 6 Median score for Arm's-length SRM in purchasing activities

The purchasing activities in arm's-length SRM that most specialists paid the greatest attention to is selecting suppliers through bidding processes by comparing prices. It followed by determining supplier quantity, making contracts and negotiating. Purchasing activity which got the least attention is making frequent small quantity orders. The median score for is 3, lower than 3.5. Specialists explained that arm's-length SRM focuses on price, competition, and goods delivery. In most purchasing activities the buyers need to contact multiple suppliers. This results in longer lead-times in the purchasing process.

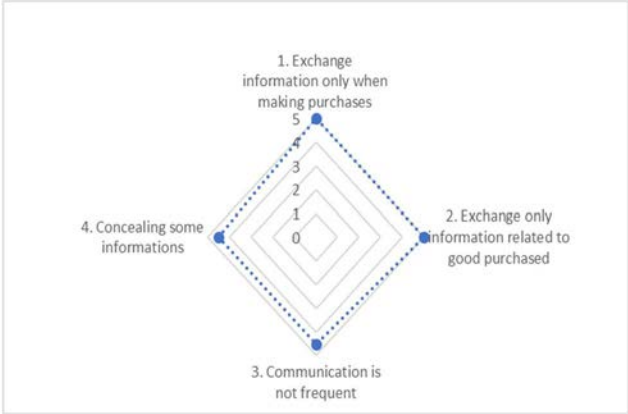

Figure 7 Median score for Arm's-length SRM in information-sharing activities

Specialists paid much attention to information-sharing of related activities in both cooperative SRM and arm's-length SRM but differ in the details of information sharing. For arm's-length SRM, the results showed that purchasing and sales only exchange information related to the products, or parts purchased when making orders. The communication is not frequent and there is concealment of information between companies.

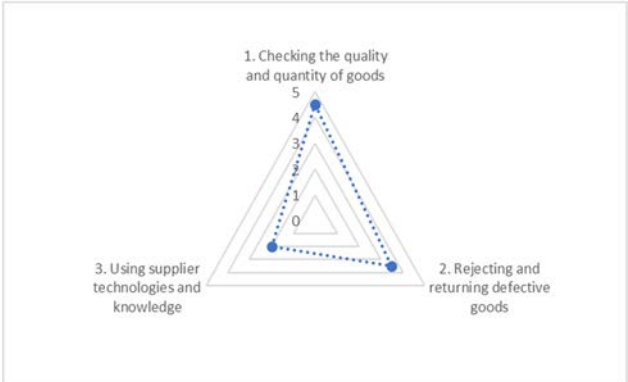

Figure 8 Median score for Arm's-length SRM in other related activities

Specialists also emphasized other related activities, such as quality and quality checking of incoming delivery, rejecting or returning defects when they have been assessed. However, they do not give priority to activities which use supplier technologies and knowledge, the median score is 2, which is lower than acceptable median

score. Specialists explained that in term of purchasing they did not use much supplier technology and knowledge; however, they need to collaborate more with supplier in the technical and technology area.

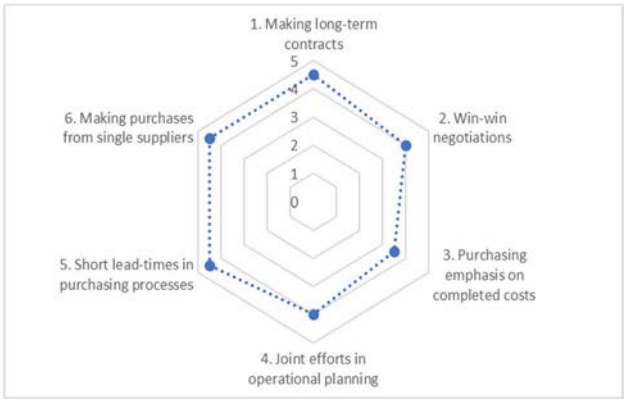

Figure 9 Median score for Collaborate SRM in purchasing activities

Figure 9 shows the level of importance of purchasing activity in cooperative SRM. Specialists gave their priority to purchasing activities relating making long-term contracts, making purchases from single suppliers, and shortening lead-times in the purchasing process, with the median score 3.5 and above. They explained that these three activities mentioned are required in cooperative SRM. Win-win negotiations and joint-efforts in operational planning are the purchasing activities which specialists gave the second priority to. According to the specialists, purchasing activity which focuses on total cost is the least important.

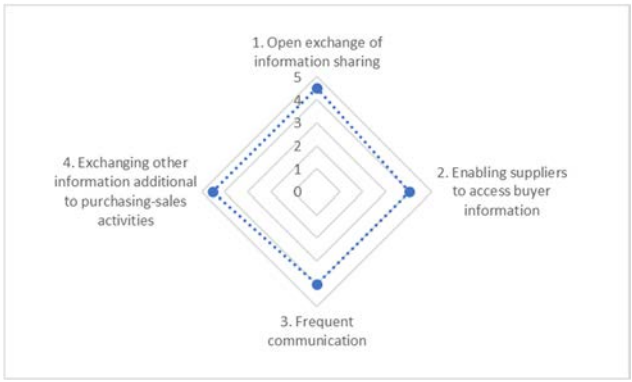

Figure 10 Median score for Collaborate SRM in information-sharing activities

From information-sharing activities, the results showed that specialists paid the most attention to open exchanges of information sharing, exchanging other information aside purchasing-sales operations, and sharing important information which is not related to purchasing and sales. It is followed by activities related to enabling suppliers to access to buyer information and those involved frequent contact between purchasing and sales. According to specialists, purchasing needs to consider which information to exchange and share, so that it will not affect the image of the organisation, the management techniques, nor the business competitiveness.

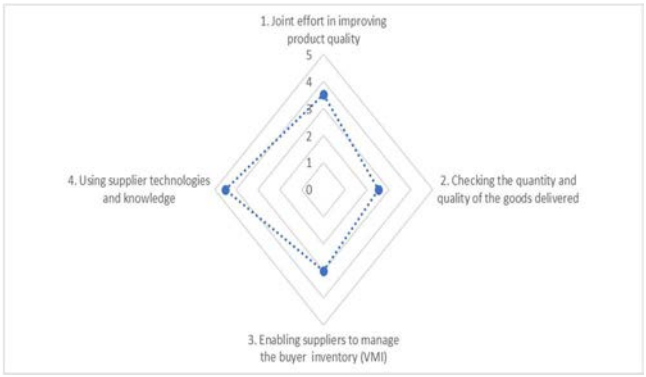

Figure 11 Median score for Collaborate SRM in other related activities

For other related activities, specialists gave top priority to using supplier technologies and knowledge, and the second lies in jointing efforts to improve product quality. However, the results showed that specialists gave low priority to activities related to VMI and activities related to quantity and quality checking of goods delivered. It is because the suppliers who are in a cooperative relationship must reach certain standards in quality and in-time delivery of their goods. The purchasing department does not have to waste time rechecking. For activities related to VMI, specialists explained that most suppliers of important aircraft parts are located abroad. Urgent delivery from abroad will increase transportation costs. As a result, purchasers will allow suppliers to store their goods in the company warehouses instead. The interquartile range for both SRM types is equal to 1, therefore, it is considered as significant, respectively.

The result of the impacts of arm's-length and cooperative SRM to purchasing performance is shown as radar chart for each sub - factors as Figure 12 - Figure 19.

Figure 12 Median score for impact of arm's-length SRM to purchasing cost

Figure 12 shows the result of the impacts of arm's-length SRM to purchasing performance in purchasing cost. The specialists agreed that arm's-length SRM reduces products price by using bidding and price comparison method. However, it increases transportation costs and administrative costs due to more frequent purchase, as shown from the median score below 3.5 in both factors. In addition, specialists noted that no clear impacts of arm's-length SRM on inventory costs were found. From further interviews, most specialists confirmed that arm's-length SRM reduces products price but increases transportation costs and administrative costs in return. While the inventory costs will vary according to delivery times and purchasing volume. Therefore, the impacts of arm's-length SRM on inventory cost cannot clearly be adjusted for.

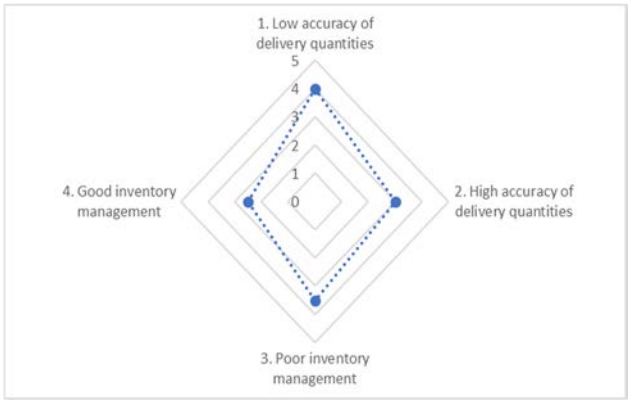

Figure 13 Median score for impact of arm's-length SRM to product purchased quantity

For the impacts on product purchase quantity, arm's-length SRM causes low accuracy in delivery quantity and poor inventory management. Due to a lack of information-sharing between purchasing and sales, and poor supplier ability to respond to immediate change, arm's-length SRM delivers poor accuracy in quantity. Furthermore, it causes poor inventory management. The specialists commented that insufficient quantities of product in stock is still the main problem for purchasing under arm's-length SRM. The median score for good inventory management and high accuracy of delivery quantities are below 3.5.

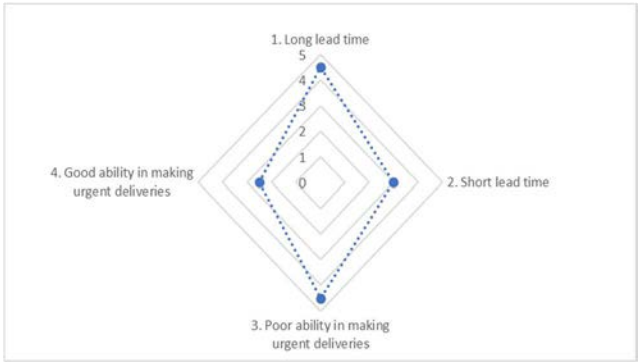

Figure 14 Median score for impact of arm's-length SRM to delivery lead-times

For the impacts of arm's-length SRM on supplier performance in terms of delivery lead-times, specialists commented that suppliers are unable to deliver goods on time as promised and take longer lead-time. Arm's-length SRM causes suppliers to be poor in responding to changes or urgent orders. The median score for short lead-times and good ability in making urgent delivery are lower than 3.5.

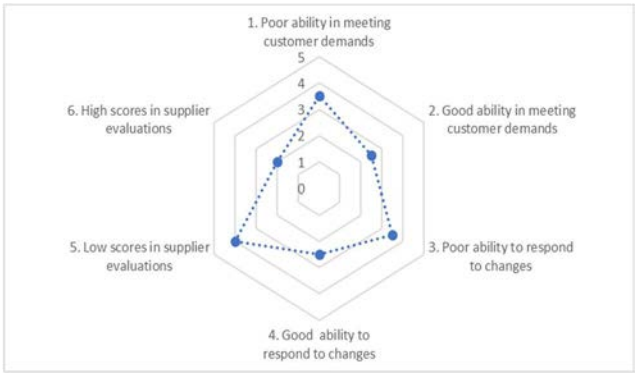

Figure 15 Median score for impact of arm's-length SRM to supplier performance

For the impacts of arm's-length SRM on supplier performance, specialists also commented that most suppliers in arm's-length relationship are poor at meeting customer demands. As a result, suppliers get standard scores in supplier evaluations and do not get a chance to develop cooperative relationships with purchasers.

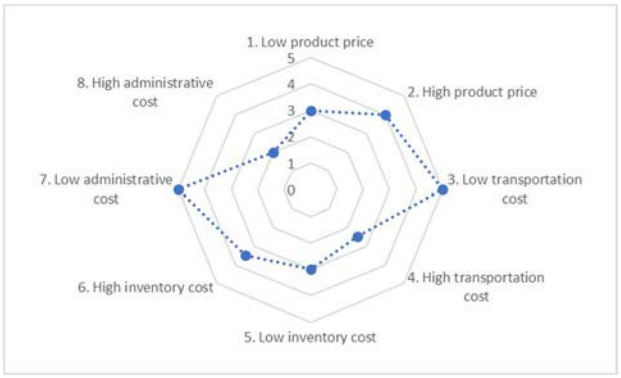

Figure 16 Median score for impact of cooperative SRM to purchasing cost

The importance level for the impacts of cooperative SRM on purchasing performance is shown in Table 16–19. For the impacts on purchasing cost, cooperative SRM causes higher product prices due to no price comparisons and limited suppliers, yet reduces transportation and administrative costs. Some specialists commented that cooperative SRM increases inventory costs, as in airline MRO suppliers permit the buyers to store their spare parts in buyer's warehouses instead. Specialists are allowed to borrow from suppliers instead of keeping more inventory or paying more for transportation when they need it in urgent.

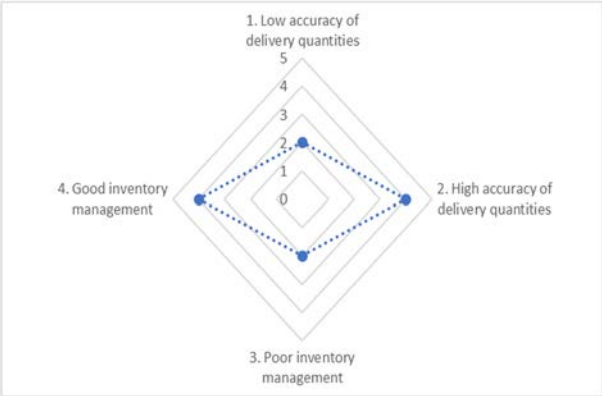

Figure 17 Median score for impact of cooperative SRM to product purchased quantity

For the impacts on products purchased quantity, the results showed that cooperative SRM leads to higher accuracy in delivery quantity and leads to good inventory management. The median score for low accuracy of delivery quantity and poor inventory management are 2, which is lower than acceptance median score.

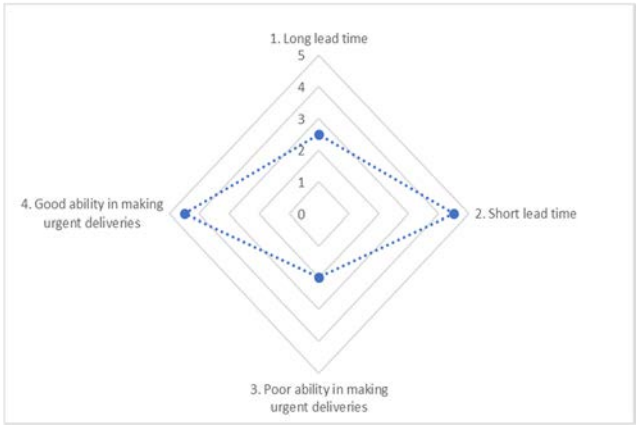

Figure 18 Median score for impact of cooperative SRM to delivery lead-times

For the impacts of cooperative SRM on supplier performance in terms of delivery lead-times, specialists commented that suppliers can deliver products on time as contractual agreement and take shorter lead-times. It makes suppliers respond efficiently to urgent orders. The results showed that open exchange of information sharing between purchasing and sales in cooperative SRM leads to better purchasing performance in terms of delivery lead-times, accuracy of delivery quantity and the ability to respond to urgent orders.

Figure 19 Median score for impact of cooperative SRM to supplier performance

For the impacts on supplier performance, all specialists agreed that joint efforts in operational planning and information sharing between purchasing and sales in cooperative SRM enhances supplier ability in meeting and responding customer demands. In addition, they agreed on using cooperative SRM with suppliers which have higher scores in evaluations. The interquartile range for both SRRM types impact on purchasing performance are equal to 1, therefore, it is considered as significant, respectively.

By analyzing the data collected according to the Delphi technique in Round 2, the data are used to build a supplier relationship management model and the impact on procurement performance as shown in Figure 20.

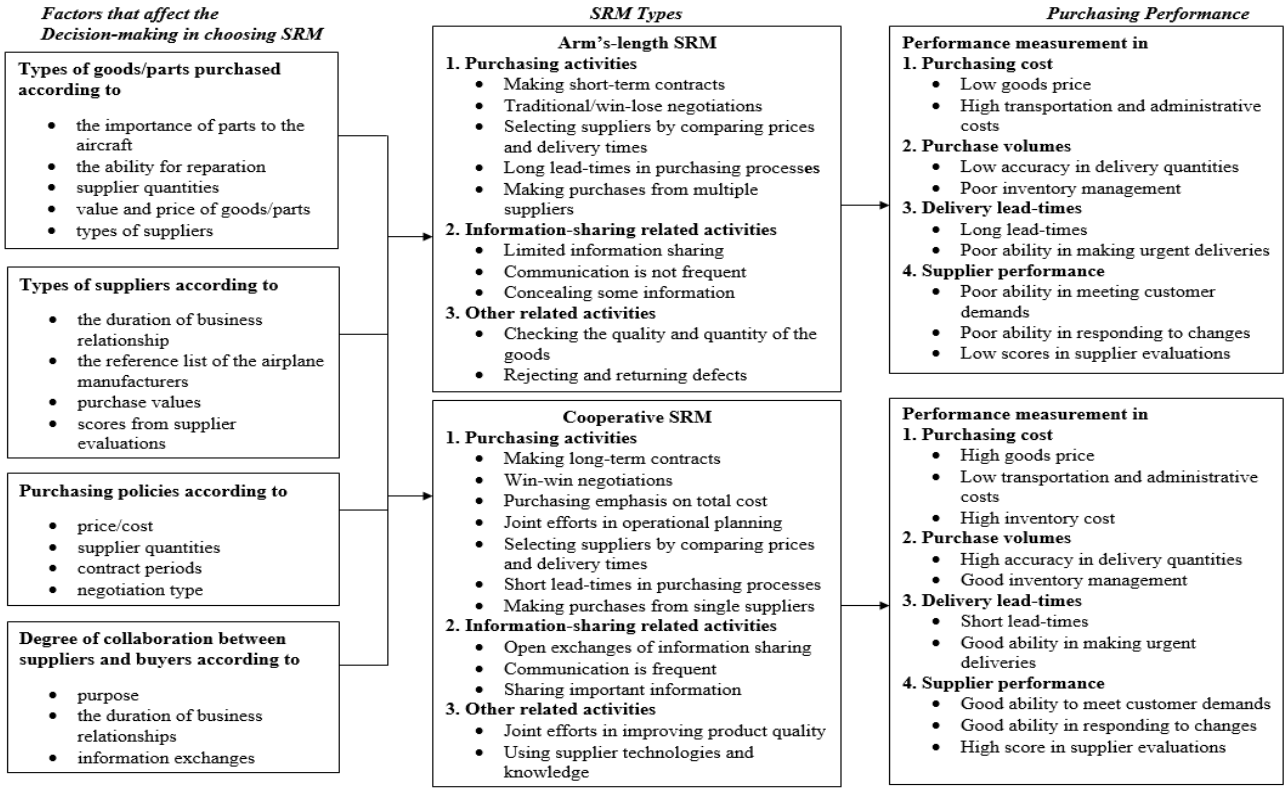

Figure 20 Conceptual Model SRM in aircraft maintenance, repair, and operation industry

5 Conclusion

5.1 Conclusion and discussion

The results showed arm's-length SRM and cooperative SRM are used in the aircraft MRO industry in Thailand, which are different from the literature review which showed four types of SRM. Factors that affect the decision in choosing SRM types are product type, supplier type, purchasing policies and collaboration degrees between purchasers and suppliers. The important activities of arm's-length SRM in the aircraft MRO industry in Thailand consist of (1) purchasing activities, including contract period, win-lose negotiation, bidding, price comparison, making purchases from multiple suppliers. (2) information-sharing related activities, including exchanging information related to the products purchased, less–frequent of communication between purchaser and supplier, and the concealment of information. (3) other activities, including checking the quality and quantities of products, and rejecting and returning defects. The important activities of cooperative SRM consist of (1) purchasing activities, including making long-term contract, win-win negotiation, purchasing which focuses on complete costs, joint efforts in operational planning and making purchases from single suppliers. (2) information-sharing related activities, including open exchange of information sharing, exchanging other information besides purchasing-sales, sharing important information and frequent contact between purchasing and sales. (3) other related activities, including joint efforts in improving product quality and using supplier technologies and knowledge.

Different SRM types have different impacts on purchasing performance. Cooperative SRM helps reduce transportation and administrative costs but increase goods price and inventory costs. The result is consistent with research of Wang (2007), Tobias and Peter (2009) and Hines (2020) indicating that strong relationship management styles help increase the efficiency of procurement costs if compared to weak relationships. However, the impact of Cooperative SRM on increasing inventory cost showed the different result from other research; because Cooperative SRM allows airline keep some of the important aircraft spare parts in their inventory before making an order. Cooperative SRM also helps improve supplier performance to meet the purchasing requirements, reduce errors in transportation and inventory management, reduce the lead-times, and respond to customer demands and changes efficiently. This research showed similar result with the study of Joseph and Christian (2001) and Wang (2007) which explained that cooperative relationship improves supplier performance and increases customer satisfaction. In contrast, arm's-length SRM causes some problems in inventory management, product delivery time, the accuracy of quantities delivered, the ability to meet customer demands and the ability to respond to changes requirement. Similar with the research result of Wang (2007), Tobias and Peter

(2009), Ghaith, Ayman and Khaled (2014) and Hines (2020), this research proved that weak relationship cause poor supplier responsibility. However, this research result showed that arm's-length SRM brings benefits in reducing purchase price and making supplier switching easier, but it increases transportation cost, especially urgent shipment cost.

In the aircraft MRO industry of Thailand, both SRMs are applied in purchasing aircraft spare parts. However, the results in this research showed that all specialists agreed that developing arm's-length SRM into cooperative SRM will bring better impacts on purchasing performance.

5.2 Limitation and suggestion

The results showed that appropriate SRM model will help improve procurement performance in aircraft MRO industry. However, this study still has some limitation in term of amount of data and limited period of time, the result only represented for specific group of industry and in some specific situations. Therefore, the results of applying the SRM model with other industries or organizations that are different from the case study may give results that do not match the research presentation.

This SRM model in the aircraft MRO industry was developed by collecting data from a small population, which suitable for using qualitative research method. Therefore, the research results may cause discrepancies if the number of populations increases. Future study using quantitative research methods is recommended to study the details of the SRM activities according to the model on how affects procurement in each aspect.

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Inventory planning of raw material using Silver Meal and Wagner Whitin Algorithm
Sapta Asmal, Deni Kurniawan, A. Besse Riyani Indah, A. Muhammad Anshar, Suradi Suradi

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Inventory planning of raw material using Silver Meal and Wagner Whitin Algorithm

Sapta Asmal
Universitas Hasanuddin, Faculty of Engineering, Department of Industrial Engineering, Jl. Malino No.8 F, Gowa, Sulawesi Selatan, Indonesia, saptaasmal@unhas.ac.id (corresponding author)
Deni Kurniawan
Universitas Hasanuddin, Faculty of Engineering, Department of Industrial Engineering, Jl. Malino No.8 F, Gowa, Sulawesi Selatan, Indonesia, dkur1998@gmail.com
A. Besse Riyani Indah
Universitas Hasanuddin, Faculty of Engineering, Department of Industrial Engineering, Jl. Malino No.8 F, Gowa, Sulawesi Selatan, Indonesia, a.besseriyani@gmail.com
A. Muhammad Anshar
Ehime University, Faculty of Engineering, Department of Materials Science and Biotechnology, Matsuyama, Japan, andimuhanshar@unhas.ac.id
Suradi Suradi
Universitas Islam Makassar, Department of Industrial Engineering. Jl. Perintis Kemerdekaan No. 9, Makassar City, South Sulawesi, Indonesia, suradi.dpk@uim-makassar.ac.id

Keywords: inventory, forecasting, Silver Meal, Wagner Whitin Algorithm.
Abstract: Material inventory planning is needed in the industrial world to advance a business because it will affect the costs incurred, the production process, and the profits generated by the company. The company has a problem that occurs when the control of raw material inventory could be more optimal. It recorded that throughout 2021, 33.647,18 meters of fabric pants were stored in warehouses. This is influenced by several factors, including the calculation of safety stock, lead time due to uncertain logistics and the selection of methods that have not been maximized. The novelty of this research is that it discusses inventory planning, the methods used are Silver Meal Algorithm and the Wagner Whitin Algorithm. Data processed is on demand for clothes and jeans throughout 2021. The results show that the Silver Meal is suitable for five materials, and the Wagner Whitin Algorithm is on one material. Companies can use both methods for each raw material. Nevertheless, it is more optimal if the company utilizes only one method for procurement of raw materials, the Silver Meal because when it is used in the long term, the cost of raw materials is less than the Wagner Whitin Algorithm. The Siler Meal's total inventory cost is Rp. 138.281.497, and the Wagner Whitin Algorithm is Rp. 170.010.097.

1 Introduction

The business world continues to experience developments in meeting the various needs of consumers who continue to grow and are competent in choosing what they need. Consumers in the middle to upper class always look for good quality at a more affordable price. To meet consumers' needs and desires, companies must have an optimal supply of raw materials. Therefore, a company must have suitable raw materials in an inventory control system [1]. Inventory is part of a company that plays a vital role in a business operation, so a company is asked to carry out the management that can help the company's conditions that occur in inventory management to achieve the desired goals. Inventory management is of utmost importance part of a company that produces a product, with inventory management, stock balance can be achieved without excess stock and shortage of stock [2]. A company needs effective inventory management so that the company can conduct a seamless production process to enable the sustainability of company processes [3]. The intended purpose is to minimize the company's costs to control its inventory. Material inventory planning is needed in an industry to develop its business because it will affect the costs incurred, the production process, and the profit generated by the company [4].

This company is an industrial company in the garment sector and has exported to various countries. Cloth pants and jeans are products that are always ordered by consumers, even though the demand is dynamic. From the results of the interviews, it is known that one of the problems faced by the company is controlling the availability of raw materials that could be more optimal. The high inventory in the warehouse causes an increase in storage costs in the warehouse and the company's profits are not optimal. Throughout 2021, it was recorded that 33.647,18 meters of fabric pants were stored in warehouses, and this led to an increase in the cost of procuring these raw materials. Fabric is the primary raw material for the production of trousers and jeans. Demand for the company constantly changes every month. The demand function depends on the marketing and operational activities of the company. Several factors that affect the

demand function include price, rebate, lead time, space, quality, and advertising [5]. In other words, the quantity of demand is dynamic, but the company uses a static inventory method. This is the cause of overstock.

Forecasting is very important and widely used at every stage of the supply chain from supplier to customer. Including the problems in meeting consumer demand. The dynamic quantity of demand for raw materials makes companies need to apply forecasting methods. Good forecasting helps companies take the right policies such as determining how many items to produce and how to set target inventory levels to minimize stockouts so inventory storage costs can be reduced [6].

Dwiputranti and Gandara conduct research with the aim of reducing consumer demand stockout fluctuations and minimizing costs incurred during one period. Based on the results of the study, it was found that the silver flour method can minimize the total cost of procurement by saving Rp. 26,773,013 or 4.15% [7].

Usman, in his research with the intention of avoiding excess or shortages of raw materials, such as in those periods previously. The result of this research is the Wagner Algorithm method Within is the best proposed method because of the high cost of inventory the most efficient use of Rp. 11,533,000 [8].

Azwir explained in his research that the consignment stock and mix strategy 4P methods are most suitable for solving inventory problems. This study obtained a decrease in inventory value by 26%, and the amount of stock decreased from 149 days to 98 days [9].

Fadhil, in his research, implemented the Min-Max stock method to solve inventory problems and the Waterfall method as an inventory information system. This research succeeded in cutting inventory costs in the company and managing inventory records in a unified and centralized way [10].

In this study, the company still uses the static inventory method, which causes overstock, so two methods are applied. The best method is chosen based on the least cost inventory.

1.1 Inventory

The term "inventory" refers to the materials, parts, and materials-in-progress that a corporation has on hand for a production process as well as the final components or products that are accessible to satisfy orders from component customers at any moment. Inventory is an activity that includes the company's goods that are intended to be sold within a certain time frame, as well as inventory of goods that are still being produced and raw materials that are awaiting use in the production process. Inventory has a very important function to support operational continuity company. This function is to provide a choice of goods in order to meet demand customers, to separate several stages of the production process, to take advantage from discounted quantities, and does not avoid inflation [11].

1.2 Forecasting

Forecasting is the art or science of predicting the future. This can be done by projecting historical data into the future with a form-systematic model. Alternatively, it could be by using a combination of mathematical models that are adjusted to the reasonable judgment of a manager [1]. Types of forecasting methods (1), (2), (3), (4), (5), (6), (7):

- Forecasting single moving average **[**12**]**

$$Ft = \frac{A_{t-1}+A_{t-2}+\cdots+A_n}{n} \quad (1)$$

- Forecasting single exponential smoothing

$$Ft = F_{t-1} + (\alpha\,(A_{t-1} - F_{t-1}) \quad (2)$$

- Forecasting the weight-moving average

$$Ft = W_1A_{t-1} + W_2A_{t-2} + \ldots + W_nA_{t-n} \quad (3)$$

- Forecasting error

$$MAD = \frac{\sum|At-Ft|}{n} \quad (4)$$

$$MSE = \frac{\sum(At-Ft)^2}{n} \quad (5)$$

$$MFE = \frac{\sum At-Ft}{n} \quad (6)$$

$$MAPE = \frac{\sum_{i=1}^{n} 100\,|At_i - Ft_i|/At_i}{n} \quad (7)$$

Description:
Ft = forecast,
At = actual demand.

1.3 The methods Silver Meal Algorithm and Wagner Whitin Algorithm

The Silver Meal focuses on the lot size that can minimize total cost per period, where the lot size is obtained by adding up the needs of several consecutive periods as a tentative lot size (8) [13].

$$K(m) = \frac{1}{m}\,(A + hD_2 + 2hD_3 + \cdots + nhD_m) \quad (8)$$

Wagner Whitin Algorithm (AWW) This technique attempts to determine the optimum lot size by evaluating all order quantities to meet the net requirements over the whole planning horizon. The math from AWW is "elegant" to achieve this goal without actually having to consider, specifically, every possible strategy. This is a solution to the lot size for the previously used net requirement schedule (9), (10), (11) [14].

$$Q_{ce} = \sum_{k=c}^{e} D_k \quad (9)$$

$$Z_{ce} = C + h\sum_{i=c}^{e}(Q_{ce} - Q_{ci}) \text{ for } 1 \le c \le e \le N \quad (10)$$

$$fe = \text{Min } \{Zce + fc\text{-}1\} \text{ for } c = 1, 2, \ldots, e \quad (11)$$

Description:
A = order cost,
D = total demand,
h = holding cost.

1.4 Safety stock

Dealing with lot sizing in inventory is increasingly complicated because of requests. Uncertainty in demand can occur because it is influenced by various factors such as weather, the economy, market competition, to the reliability of suppliers. From the time an item is ordered until it is delivered, it might take anywhere from a few hours to several months. The lead time is the amount of time between placing an order and when the products actually arrive. The availability of the items and the distance between the buyer and the supplier have a big impact on the waiting time. Due to the grace period, safety stock, or inventory set aside for needs while awaiting the delivery of the items, is important. To deal with demand uncertainty, safety stock has been employed extensively. A level of item, also known as a stock keeping unit (SKU), known as safety stock is kept in a warehouse to manage unforeseen demand [15].

Safety stock is a unit of inventory that is constantly present in a business to prepare for demand variations and prevent stockouts. Meanwhile, safety stock (safety stock) is an additional inventory stored to protect against variations in sales levels or more recently in manufacturing or delivery [16,17].

2 Methodology

This study includes quantitative research using historical data on demand for cloth pants and jeans from January 2021 to June 2022. Other data were obtained from interviews with this company.

After all the data is collected, the data is processed by following these steps:

- Forecasting single moving average (equation 1),
- Forecasting single exponential smoothing (equation 2),
- Forecasting the weight moving average (equation 3),
- Calculation of forecasting error (equation 4, 5, 6, 7),
- Calculate inventory costs which include ordering costs (A) and holding costs (h),
- Calculating inventory planning costs using the Silver Meal (equation 8),
- Calculating inventory planning costs using the Wagner Within Algorithm (equations 9, 10, 11),
- Calculating safety stock,

$$SS = Z \times \sigma \times \sqrt{L} \quad (12)$$

Description:
SS = safety stock,
Z = service level,
σ = standard deviation,
L = lead time.

- Comparing calculation costs with the company

Holding costs consist of maintenance costs, warehouse electricity costs, and warehouse keeper salaries, which are calculated based on the capacity of the warehouse and each raw material.

Table 1 Holding cost

Materials	Cost/Unit/Month (Rp)
Fabric	657
Yarn	1.460
Zipper	1.460

The cost of messages for the procurement of raw materials is the total telephone, administrative, and shipping costs for each raw material. The procurement of raw materials for fabric is Rp. 6.800.000, yarn and zipper is Rp. 1.500.000. The following are the details of the booking fees made by PT. XYZ

Table 2 Ordering cost

Ordering Cost	Cost
Administration Fee	Rp. 150.000
Telephone	Rp. 150.000
Shipping cost Fabric	Rp. 6.500.000
Shipping cost Yarn	Rp. 1.200.000
Shipping cost Zipper	Rp. 1.200.000

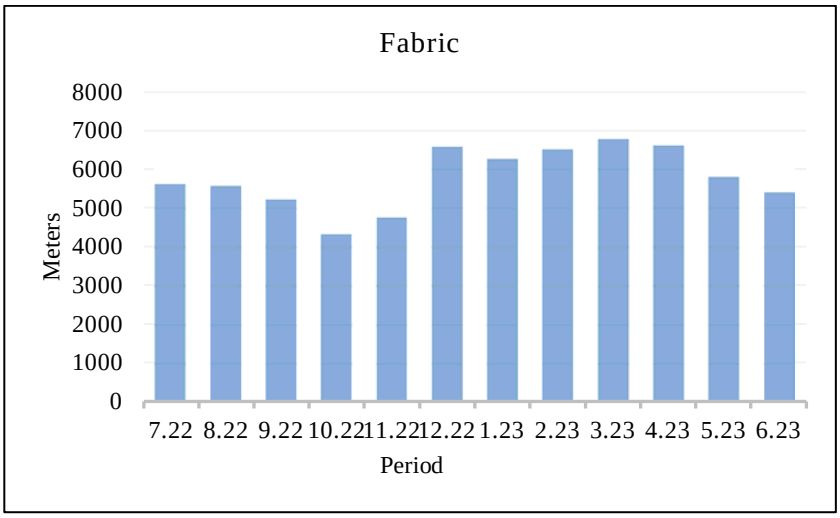
3 Result and discussion

3.1 Forecasting

From the forecast error rate calculation, the method chosen for the demand for cloth pants and jeans is the weight moving average because it has a minor error value. The following forecast results from cloth pants and jeans.

Table 3 Raw Material need for cloth pants

Period	Fabric (Meters)	Yarn (Rolls)	Zipper (Pieces)
July 2022	5615.4	428	4000
August 2022	5572.9	424	4000
September 2022	5222.8	396	3700
October 2022	4334.2	328	3100
November 2022	4750.9	360	3400
December 2022	6579.2	500	4700
January 2023	6270.2	476	4500
February 2023	6509.7	492	4600
March 2023	6786.1	516	4800
April 2023	6613.2	500	4700
May 2023	5795.4	440	4100
June 2023	5397.2	408	3900
Total	**69447.2**	**5268**	**49500**



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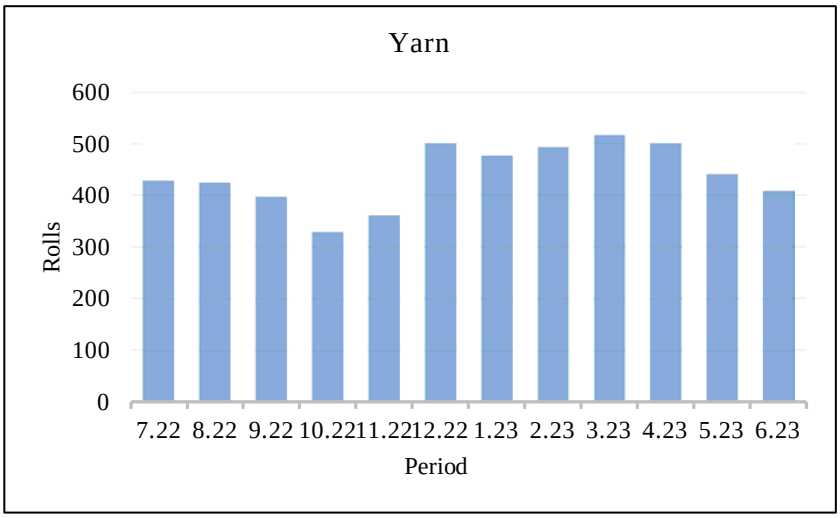

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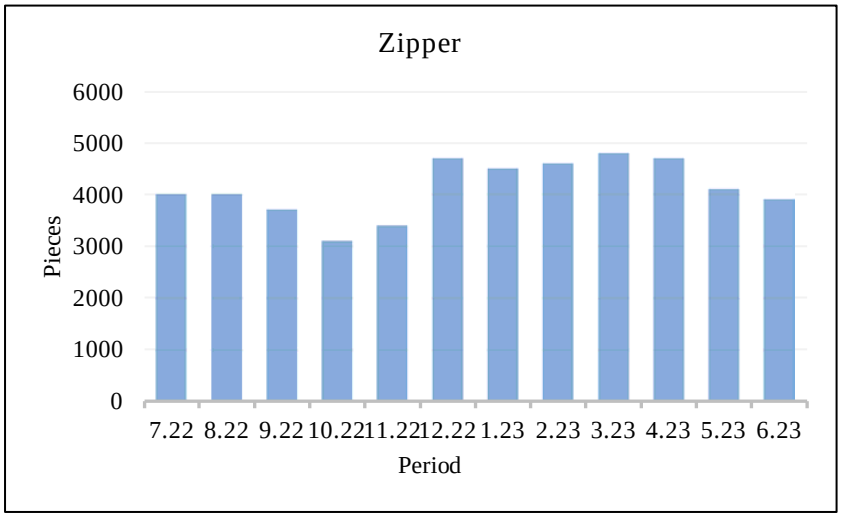
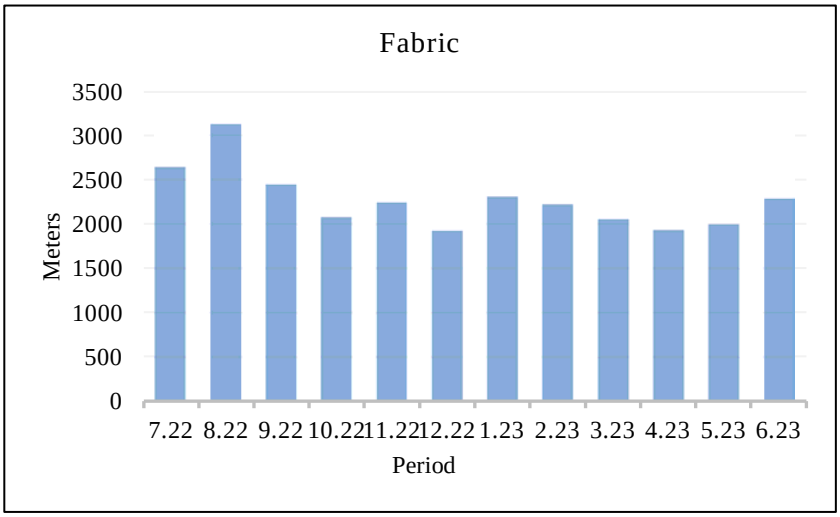


(c)

Figure 1 Materials needs for cloth pants

Table 4 Raw Material needs for jeans

Period	Fabric (Meters)	Yarn (Rolls)	Zipper (Pieces)
July 2022	2641.693	208	1900
August 2022	3122.001	244	2300
September 2022	2439.681	192	1800
October 2022	2072.387	164	1500
November 2022	2237.669	176	1600
December 2022	1918.406	152	1400
January 2023	2305.477	180	1700
February 2023	2215.067	176	1600
March 2023	2055.435	164	1500
April 2023	1925.469	152	1400
May 2023	1997.515	156	1500
June 2023	2284.287	180	1700
Total	**27215.088**	**2144**	**19900**



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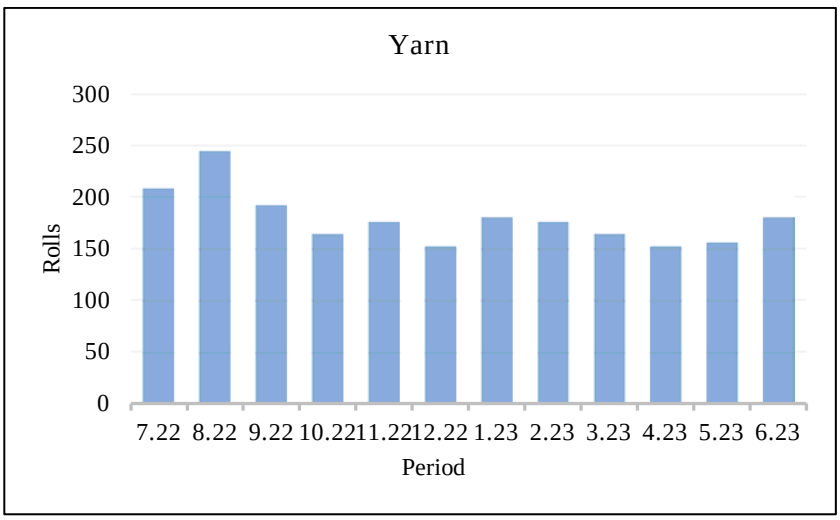

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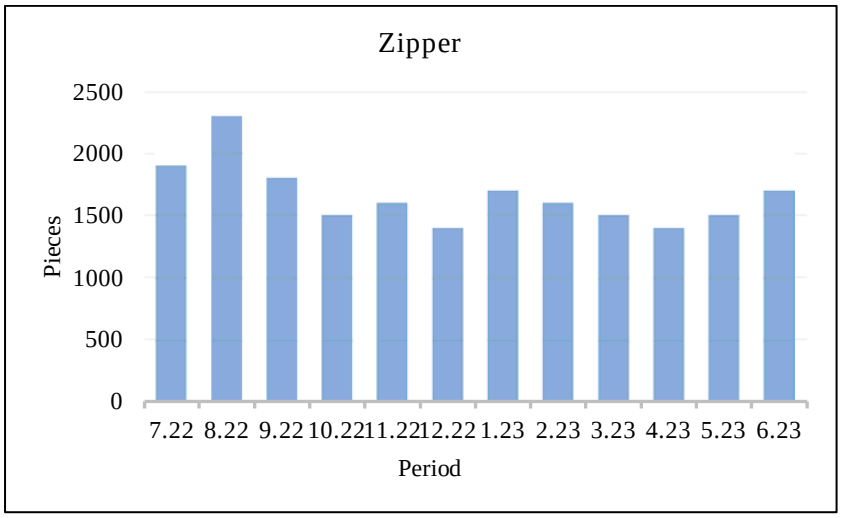

(c)

Figure 2 Materials needs for jeans

3.2 Safety stock

An additional inventory known as "safety stock" is kept on hand to guard against or sustain the risk of material shortages (stock out). Using the findings of the calculations, the six different categories of raw materials were given safety stock. The quantity of safety stock will vary depending on a number of factors, including the volume of orders, the degree of service, and the lead time. Based on the calculation results, different safety stocks were obtained for the six types of raw materials, namely 283.86 meters for fabric trousers. The company must have a minimum inventory of 283.86 meters of fabric pants to anticipate raw material shortages in the production process. Similarly, twenty rolls of yarn for fabric pants with safety stock, 200 pieces of zippers for fabric pants, 124.56 meters of jeans fabric, eight rolls of yarn for jeans, and 100 pieces of jeans zippers. The size of the safety stock will depend on several things, such as order frequency, service level used, and lead time.

Table 5 Safety stock

Materials	Safety Stock
Fabric Pants	283.86 meters
Yarn Fabric	twenty rolls
Zipper Fabric	200 pieces
Fabric Jeans	124.56 meters
Yarn Jeans	eight rolls
Zipper Jeans	100 pieces

3.3 Inventory planning

Inventory planning calculation uses two methods: Silver Meal and Wagner Whitin Algorithm. These two methods determine which produces the lowest inventory cost, and the Silver Meal determines the average cost per period.

Additional orders are made when the average cost of the second period is still less than the average cost of the first period. Suppose the cost of ordering the second period is higher than that of ordering the first period. In that case, the calculation is carried out as before, starting again with the previous period. Meanwhile, the Wagner Whitin Algorithm aims to find the most optimal alternative among all existing alternatives. This method's stages include calculating all alternative orders based on the period. If we have obtained the results of alternative calculations, the next step is to find the lowest cost for each period. Then the lowest cost from each period becomes a reference to determine how many times to order from each item.

In comparison to the total inventory cost supplied by the company, calculations using the suggested approaches Wagner Whitin Algorithm and Silver Meal Algorithm produced a minimum total inventory cost. The ideal order quantity utilizing the two recommended techniques, which is smaller than the total cost of inventory, shows the difference in the overall cost of the company's inventory with the proposed method. The results differ from the company's total inventory expenses since the optimal order quantity will lower the ordering cost, which is rather high. The table below shows the prices for the two and the company's procedures.

Table 6 Comparison of total inventory cost

Materials	Total Inventory Cost		
	Silver Meal (Rp)	AWW (Rp)	Company's (Rp)
Fabric Pants	66.838.881,1	72.329.250,1	99.447.535
Yarn Fabric	7.418.540	11.313.220	16.359.260
Zipper Fabric	7.794.340	11.357.020	15.402.960
Fabric Jeans	47.029.416,3	66.421.726,9	56.338.048,6
Yarn Jeans	4.956.400	5.571.940	7.113.980
Zipper Jeans	4.243.920	3.016.940	7.974.500
Total	**138.281.497,4**	**170.010.097**	**202.636.284,6**

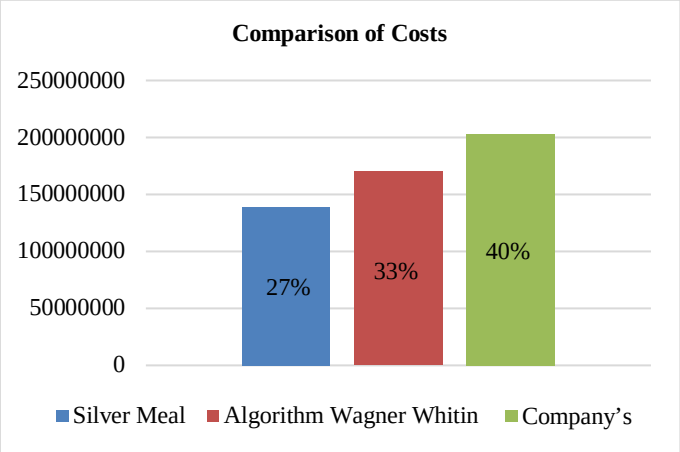

Figure 3 Comparison of costs

Table 6 and figure 3 show differences in total costs using the three methods. The company's calculation results are more expensive than the two tested methods, namely the Silver Meal Algorithm and the Wagner Whitin Algorithm.

The computation yields Silver Meal have a nominal total inventory cost than the Wagner Whitin Algorithm method, and this is influenced by ordering costs and storage costs. Although storage costs using the Wagner Whitin Algorithm are, on average, smaller than the Silver Meal, the ordering costs using the Wagner Whitin Algorithm are more significant than the Silver Meal method.

Based on the results of the calculations, the most recommended and suitable method is to be applied at PT using the two proposed methods. XYZ is a Meal for the raw material for making cloth pants, fabric jeans thread Silver. As for the zipper of jeans method, using the Wagner Whitin Algorithm is more optimal. However, it is more optimal if the company utilizes only one method for the procurement of raw materials, namely the Silver Meal Method because when used in the long term, the costs incurred for the procurement of raw materials are lower than the Wagner Whitin Algorithm method.

4 Conclusions

The conclusion of this study is the result of data processing that has been carried out to answer the research objectives. The company experienced an increase in storage costs because it did not take into account safety stock and did not choose a method that was not optimal. The company procures its inventory the use of Fixed Order Quantity with the order quantity of raw materials for making as much as 5000 pieces of pants per order.

Ordering technique (lot size) using two methods, namely the Silver Meal produces a total inventory cost that is smaller than the Wagner Whitin Algorithm except for zipper jeans small order interval with a frequency of ordering fabric pants six times, thread for fabric pants for three times, zipper fabric five times ordering, jeans fabric material times four ordering, jeans thread zipper two times and ordering jeans two times. Method Wagner Whitin The algorithm generates a total inventory cost that is higher than the Silver Meal but lower than the company's approach because to the small order interval with the frequency of ordering fabric four times for pants, fabric pants for two times ordering, zipper cloth pants ordered two times, jeans fabric material eight ordered times and jeans one time. As for the zipper of jeans, one order is made so that the costs incurred are smaller than the Silver Meal Method.

Companies can use both methods for each raw material. However, it is more optimal if the company utilizies only one method for the procurement of raw materials, namely the Silver Meal Method because when used in the long term, the costs incurred for the procurement of raw materials are lower than the Wagner Whitin Algorithm method. This research can be developed again at the shelf time of the material so that it can maximize the existing inventory so that there is no dead stock. For further research, it is necessary to add research objects and not focus on just 2 products so that the results obtained are more optimal for the company. because the more objects that are predicted, the smaller the percentage of forecast error.

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Improving last mile distribution systems through the Internet of Things: a South African case
Masithembe Kafile, Thokozani Patmond Mbhele

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Improving last mile distribution systems through the Internet of Things: a South African case

Masithembe Kafile
University of KwaZulu Natal, 228 High Bury Park, Kuils-River, Cape Town, Western Cape, South Africa, masithembekafile@gmail.com (corresponding author)
Thokozani Patmond Mbhele
University of KwaZulu Natal, University Road, Westville, 4000, Durban KwaZulu Natal, South Africa, mbhelet@ukzn.ac.za

Keywords: logistics, last-mile, distribution, IoT.
Abstract: The study investigates the impact of the IoT on the cost and quality of last-mile logistics, the critical and often challenging final phase of the supply chain. With the relentless growth of e-commerce and the increasing demands for efficient and reliable delivery services, understanding how IoT affects last-mile logistics is increasingly becoming important. Through the integration of IoT technologies such as GPS tracking, RFID systems, and real-time data analytics, the study aimed to assess the extent to which the application of the IoT affects the cost and quality of last-mile distribution in South Africa. As a result, the study provides valuable insights into the potential cost savings or increases associated with IoT adoption, quality challenges and areas of improvement, customer satisfaction and the overall performance of last-mile distribution systems. The methodology involves the collection of primary data from selected distribution companies in South Africa. Statistical software was used to analyse the data to shed light on the tangible benefits and challenges associated with IoT adoption in last-mile logistics as they relate to cost and quality. The research findings indicate that implementing IoT in last-mile distribution systems in South Africa can significantly improve efficiency and effectiveness. The IoT integration with existing infrastructure enables seamless communication, proactive decision-making, and reduced delivery delays. Overall, by leveraging IoT technologies and real-time data analysis, organisations can optimise their distribution processes, reduce costs, improve quality, and enhance overall customer experience.

1 Introduction

Last-mile delivery is a critical component of the supply chain, but it faces numerous challenges, exacerbated by the complexities of the Covid-19 era [1]. While it is the most crucial link, [2] claims that it is also the least effective. Efforts to eliminate obstacles and enhance transportation quality have led to a focus on consumer-driven logistics, cost reduction, and innovative solutions like micro-hubs and crowd delivery [3]. [4] suggest that in recent years, the global demand for efficient and reliable last-mile distribution systems has been on the rise, driven by the rapid growth of e-commerce and the need to reach geographically dispersed customers and during the covid 19 years, this growth doubled, causing a need for innovative solutions to the challenges associated with the increasing demand of home deliveries. South Africa, as a rapidly developing nation with a thriving digital economy, is not immune to the challenges associated with last-mile logistics [5]. This study assesses how IoT adoption affects the cost and quality of last-mile distribution in South Africa. It aims to uncover potential cost savings, quality enhancements, customer satisfaction improvements, and overall performance of the LMD sector. Leveraging IoT's capabilities can enhance efficiency, visibility, and responsiveness in deliveries, leading to satisfied customers and reduced operational costs. By addressing South Africa's unique logistics challenges, this research paves the way for more efficient and sustainable distribution operations, enabling businesses to deliver goods with improved quality and cost efficiently.

2 Literature review

2.1 Last-mile distribution systems

[6] define Last Mile Distribution Systems as the last leg of the supply chain, covering the transportation and delivery of goods to the final point of consumption. Last-Mile Distribution Systems are crucial for ensuring timely and efficient delivery, as well as customer satisfaction. [7] opine that this stage often involves complex logistical operations, including route optimisation, inventory management, and coordination with various stakeholders such as couriers, drivers, and customers. Efficiency and effectiveness in last-mile distribution are vital for customer satisfaction, cost optimisation, and overall business success. Customers are provided with a plethora of online purchasing options, which places greater pressure on last-mile providers to ensure their service delivery and offerings are optimal at all times [8]. It is imperative for last-mile service companies to maintain cost-effectiveness and superior quality of the service provided despite the increased demand for deliveries for them to flourish in the online market [9].

2.1 Internet of Things (IoT) in supply chain management

2.1.1 Overview of the Internet of Things (IoT) technology

The IoTs is not a single technology, but rather a creative alliance of numerous complementary technologies working together to close the gap between the digital and physical worlds [10] and [11]. The phrase "Internet of Things" was first used in 1999 by the Massachusetts Institute of Technology's (MIT) Auto-ID Center for SCM to describe a method of tracking items via the Internet using radio-frequency identification (RFID) linking to an Electronic Product Code (EPC) serving as a unique identifier for each individual item [12]. Since then, the definition of a "Thing" has expanded to cover a variety of digital gadgets that can be uniquely identified, read, sensed, addressed, and operated autonomously through the Internet. Examples include RFID, sensors, actuators, cell phones, and smart products [13]. By utilising the Internet as a communication infrastructure, a means of data storage, and a platform for data processing and synthesis, these authors further contend that the capabilities of IoT devices are hypothesized to surpass the inherent functionality of any item. Today, social networks, cloud computing, big data analytics, and GPS telematics all contribute to the IoT platform's expansion [14]. Self-awareness, individuality, control, interconnection, adaptability, transformability, synergy, self-decisiveness, and strategic behaviour are important IoT features [15].

2.1.2 Applications of the IoT in Supply Chain Management

[16] reported that SCM has seen a transition that takes the form of a basic RFID-based tag for product recognition, then adopts sensor technology and then communicates devices to a smarter supply chain. The authors found that technical advances have opened the way not only to track the goods but also to predict situations for avoiding losses for the company and safeguarding the goods properly for the right individual to collect information and convey them to the right person at the right time for the early delivery of the goods. [17] showed that tools like RFID followed by wireless sensor networks and then middleware, web platforms and cloud computing play a significant role in integrating the supply chain information digitally. Adopting technologies such as the IoT in SCM also decreases the times required to purchase or buy products and services and offers improved communication using items that in effect speed up the efficiency of companies [18]. The study also showed that the Internet of Things is strong in terms of visibility, auto-capture and sharing of information. This in turn provides a positive effect on costs, followed by quality and supply chain flexibility in integrated supply chain businesses.

[19] the IoT in the supply chain management sector is not just for big, resourceful companies and their SCs. It is a widely used and widely accessible technology for a variety of SCM functions, such as information linking with vendors, gathering real-time progress data from vendors, producing real-time quality/maintenance data, inventory tracking, and information sharing. Enhancing reverse logistics, enabling quality monitoring and quality-controlled logistics, collecting product data while in use, and cooperative ordering are all ways to increase operational efficiencies and income prospects [20]. Making better operational decisions and improving strategic outcomes at the SC and firm levels is ultimately made possible by the availability and analysis of IoT-enabled real-time data [21]. For instance, [22] describes how IoT and big data analytics are used in a logistics company to enhance driver safety, operational effectiveness, and environmental sustainability. Cost implications play a crucial role in the adoption of IoT-enabled last-mile distribution systems. Implementing IoT technologies in the context of last-mile logistics involves significant upfront and ongoing costs, including device procurement, network infrastructure, data storage, and maintenance. For organisations operating on tight budgets or with limited resources, the financial burden of IoT implementation can pose a significant challenge [23]. For this reason, careful assessment of the return on investment is essential, along with considering the long-term cost benefits when planning the integration of IoT solutions [24]. Moreover, the scalability of IoT adoption becomes a complex task due to the heterogeneity of products and underlying technologies. Building an infrastructure capable of supporting thousands of connected products requires substantial investment. Therefore, addressing cost-related concerns and finding cost-effective solutions is vital for successfully improving last-mile distribution systems through the Internet of Things [25]. Although there is a definite need for IoT application in the last mile distribution of goods processes [26] further report that due to how fast technology is moving, there is a reluctance from top management to invest in any form of technology. This resulted in a fear that it would be deemed obsolete within a few years [27].

3 Methodology

3.1 The research approach and data collection methods

This study follows a quantitative research approach. The quantitative analysis of the impact of IoT on the cost and quality of LMD companies helped to evaluate the potential benefits of integrating IoT technologies in improving last-mile distribution in South Africa. A structured survey questionnaire was designed to collect data from six last-mile distribution companies within the Durban region of south Africa, using a purposive sampling technique, two hundred and ten (210) participants were selected for the study as the sample derived from the population including logistics managers, delivery personnel, and administrators. Consequently, only one hundred and seventy-nine (179) questionnaires were useable. The survey was designed to gather information on the challenges faced, the potential benefits of IoT adoption,

and the critical factors influencing cost and quality while ensuring the anonymity and confidentiality of the participants. The questionnaires were then coded into Excel and exported into the Statistical Package for Social Sciences (SPSS), version 27.0. Frequency distribution and descriptive statistics were employed in the analysis of the quantitative data.

3.2 Population, sampling and sample size

A population can be defined as the total number of units, elements, or cases such as individuals, organisations, items, or events from which a sample can be drawn for study purposes [28]. The population in the context of this research was selected using purposive sampling and included six last-mile distribution companies in Durban. The practical reason for excluding other LMD companies in South Africa is that Durban is one of the three biggest cities in South Africa with an effective and sustainable logistics sector, therefore, this population was a good representation of the entire country. According to [29] sampling is "the process of selecting a sufficient number of the right elements from the population so that a study of the sample and an understanding of its properties allow for generalisation to the population elements". Alternatively put, sampling is the procedure used to gather data about a population's overall makeup through examination of a subset of it. Based on the formula for sample size with the margin of error set at 5%, the sample size for this study was 210 with a response rate of 179. Using Yamane's statistical formula to determine the adequate sample size of a population of 440 under study. This would hence be (1):

$$n = \frac{N}{(1+N(e)^2)} \quad (1)$$

Where:
n - signifies the required sample size
N - signifies the population under study
E - signifies the margin of error. It sets the accuracy of the sample proportions. With an accuracy of plus or minus 5%, then e is usually set at 0.05.

The study illustrates with the above formula to determine the sample size from a given population size of 440 (N) with a margin of error (e) of 0.05 by substituting the given variables as follows (2):

$$n = \frac{440}{(1+440(0.05)^2)} \quad (2)$$

$$n = \frac{440}{2.1}$$

n=210

Therefore, a sample size of 210 respondents out of a population of 440 would be an acceptable number of responses to maintain a 95% confidence level.

4 Results and discussion

Based on the overall aim of the study, this section presents the results and analysis of the collected data, which serve as the foundation for interpretation and the discussion of the results.

4.1 The influence of the IoT in the LMD industry in South Africa

In asking the respondents about their perceived or experienced influence of IoT in the LMD industry in South Africa, the researchers aimed to ascertain the specific areas in which IoT had a discernible impact on both cost and quality. This information can assist organisations in directing their focus towards the most promising IoT applications within the LMD sector. Evaluating the advantages of IoT in LMD not only facilitates the assessment of returns on investment (ROI) but also provides a clearer understanding of the value proposition associated with the implementation of IoT solutions. Through the systematic collection of data on positive outcomes, this study aimed to quantitatively measure the influence of IoT across various dimensions, including cost savings, increased productivity, error reduction, quality enhancement, heightened customer satisfaction, and the attainment of competitive advantage. The resultant research findings are poised to make substantial contributions to the establishment of industry best practices and guidelines. These insights can be shared among industry professionals, policymakers, and stakeholders to enable well-informed decision-making, promote collaborative efforts, and accelerate the adoption of IoT solutions in the LMD sector.

4.1.1 Use of the IoT in last-mile logistics in South Africa

The researcher asked this question to understand adoption rates and gain insight into the extent to which IoT technologies have been adopted in the industry. This information can assist in identifying trends and assessing the current level of implementation as well as in understanding the current landscape, challenges, and opportunities in this field.

Table 1 Use of IoT technologies in organisational operations

	Responses (N)	Percent	Percent of Cases
Tracked vehicles	177	23.70%	98.90%
Expanded delivery routes	160	21.40%	89.40%
Expansion and use of drones	10	1.30%	5.60%
Improved deliveries	126	16.90%	70.40%
Order fulfilment point	137	18.40%	76.50%
Packaging and labelling	51	6.80%	28.50%
Defects management	38	5.10%	21.20%
Reverse logistics	47	6.30%	26.30%
Total	**746**	**100.00%**	**416.80%**

The researchers inquired about the IoT technologies currently in use within the organisations to evaluate their impact on cost and quality aspects of operations. The descriptive analysis revealed that out of a total of 746 instances where smart technology influenced operations, a significant 98.9% of these cases were related to tracked vehicles. This indicates a pronounced reliance on IoT for monitoring and managing transportation logistics, which can have direct implications on cost efficiency, route optimisation, and overall quality of service. Moreover, the descriptive findings revealed that in 89.4% of cases where smart technology played a role in the respondents' organisations, it was associated with expanded delivery routes. This expansion might signify potential cost savings through efficient route planning and quality of service, as it can impact delivery times and customer satisfaction. Additionally, in 76.5% of cases, smart technology impacted the order fulfilment point. This suggests potential improvements in inventory management and order processing efficiency, which can positively affect both cost control and the accuracy and timeliness of deliveries, directly impacting quality. Furthermore, in 70.4% of instances, smart technology was linked to improved deliveries. This improvement may encompass various aspects, including on-time deliveries, reduced errors, and enhanced customer experiences.

To further explore the integration of IoT within the LMD sector, respondents were asked about the prevailing IoT technologies employed within their organisation. The findings showed that out of 399 cases of technologies that are currently most used, 99.4% (n=178) were linked to End-to-End tracking, revealing its prominent role. Furthermore, 97.2% of these cases were credited to the Global Positioning System (GPS), underscoring its wide adoption. In contrast, a mere 5.0% (n=9) of the cases were associated with sensors, signifying their limited usage, while 6.1% of the cases were attributed to Radio Frequency Identification (RFID). These results hold significant implications for both cost-effectiveness and quality enhancement within the LMD industry.

Table 2 Commonly used IoT technologies

	Responses (N)	Percent	Percent of cases
End-to-end tracking	178	44.6%	99.4%
Security cameras	27	6.8%	15.1%
Sensors	9	2.3%	5.0%
Radio Frequency Identification (RFID)	11	2.8%	6.1%
Global Positioning System (GPS)	174	43.6%	97.2%
Total	**399**	**100.0%**	**222.9%**

Table 3 Business processes affected by IoT

	Responses (N)	Percent	Percent of cases
Reporting and decision making	178	33.5%	99.4%
Order fulfilment	176	33.1%	98.3%
Fleet management	177	33.3%	98.9%
Total	**531**	**100.0%**	**296.6%**

Furthermore, respondents were asked what business processes are affected by IoT in the organisation. the descriptive analysis revealed that among the 531 cases of business processes influenced by IoT, the majority (n=178; 99.4 %) were attributed to reporting and decision-making, indicating that IoT technology plays a crucial role in enhancing data-driven decision-making processes. Additionally, 98.9% of the cases were linked to fleet management, revealing how IoT contributes to cost optimisation in this area as IoT devices can provide real-time tracking and monitoring of vehicles, leading to more efficient route planning, reduced fuel consumption, and maintenance cost savings, all of which positively impact the organisation's overall cost structure. While 98.3% of the cases were associated with order fulfilment, underscoring the importance of IoT in streamlining supply chain operations. Improved visibility and tracking of inventory and orders can result in faster and more accurate order processing. These results highlight that IoT significantly affects both cost and quality in various business processes, emphasising its potential to drive efficiency, reduce expenses, and enhance decision-making within the organisation.

Table 4 Challenges of the IoT

Challenges	Responses (N)	Percent	Percent of cases
Connectivity	33	7.20%	18.40%
Data collection and processing	169	36.90%	94.40%
Limited bandwidth	23	5.00%	12.80%
Cybersecurity	175	38.20%	97.80%
Lack of regulation	58	12.70%	32.40%
Total	**458**	**100.00%**	**255.90%**

The descriptive analysis of the challenges faced by the IoT in the LMD industry indicates that cybersecurity is the most prominent concern, with 97.8% of respondents identifying it as a challenge. This has significant implications for both cost and quality. Investing in robust cybersecurity measures can be costly, but it is essential to protect sensitive data and ensure the quality of IoT systems by preventing breaches and data loss. Similarly, (94.4%) of respondents highlighted data collection and processing as a challenge. Efficient data collection and processing are

vital for delivering high-quality services and products in the LMD industry. However, implementing the necessary infrastructure and technologies for data management can be costly. Furthermore, if data collection and processing are not done accurately, it can lead to errors and lower the quality of insights and decisions made using IoT data. The challenges related to lack of regulation (32.4%) connectivity (18.4%) and limited bandwidth (12.8%) also have cost and quality implications. The absence of clear regulations can create uncertainty and compliance costs for businesses, impacting their cost structure. Additionally, poor connectivity and limited bandwidth can hinder the real-time functionality and effectiveness of IoT systems, potentially compromising the quality of services and data analysis.

In summary, the identified challenges in the IoT LMD industry, including cybersecurity, data collection and processing, lack of regulation, connectivity, and limited bandwidth, all have varying degrees of impact on both cost and quality. Addressing these challenges effectively is crucial for LMD businesses to maintain high-quality services and products while managing their costs efficiently.

5 Conclusion

This section contains the study's concluding remarks in relation to the research objectives, recommendations and summary of findings and implications for the study.

5.1 Summary of findings

The study found a strong correlation between cost and quality efficiency in LMD businesses that have integrated IoT technologies. Key factors influencing cost efficiency and quality management include accurate and timeless collection of data through IoT sensors which equips businesses to make informed decision making, optimises resource allocation and minimises waste all enhancing both cost and quality efficiency. These findings align with previous research on Logistics 4.0 initiatives which benefit the economy by lowering logistical expenses, increasing productivity, and improving customer satisfaction [30].

IoT innovations, such as real-time predictive analytics, offer new opportunities for both traditional and online retailers to enhance customer experiences, optimise inventory management, and improve supply chain operations. By adopting these IoT advancements, retailers can stay competitive and deliver seamless experiences to customers [31-35]. The study also revealed that IoT technologies positively influence the responsiveness and performance of last-mile logistics companies. Elements such as security cameras, IoT-enabled vehicles, sensors, RFID, and GPS contribute to increased productivity, efficiency, and customer satisfaction by reducing lead times, defects, and information inaccuracies. Additionally, end-to-end supply chain visibility provided by these elements enables partners to enhance market responsiveness and mitigate supply chain disruptions.

5.2 Recommendations

Based on the study findings, the key recommendations for last-mile logistics businesses and other stakeholders in the industry are to prioritize the integration of IoT technologies into their operations for cost-efficiency, quality, and sustainability in the LMD sector. This includes investing in cybersecurity by implementing robust security measures and encryption protocols to safeguard sensitive data and IoT devices from potential threats. The second recommendation is to improve data collection and processing capabilities, focusing on data accuracy and real-time analysis, which will enable better decision-making and resource optimisation, ultimately reducing wastage and improving both cost and quality efficiency. Furthermore, it is crucial for businesses to invest in security cameras, IoT-enabled vehicles, sensors, RFID, and GPS to boost productivity, efficiency, and customer satisfaction in the last-mile delivery process. Collaboration with regulatory bodies and industry stakeholders to establish comprehensive guidelines and standards for IoT application in the LMD sector, ensuring compliance and accountability, is also advisable. Additionally, the study recommends the use of alternative connectivity solutions, such as edge computing and 5G networks, to mitigate connectivity issues and enhance data transmission efficiency. Lastly, stakeholders across industries should recognise the value of IoT technologies and consider their adoption in day-to-day operations and future planning, as the digital revolution continues to reshape the e-commerce landscape. This proactive approach will help last-mile logistics businesses maintain high-quality services while efficiently managing costs, fostering innovation, and sustaining their competitive edge in the face of evolving challenges and opportunities in the sector.

5.3 Contribution and practical implications of the study

5.3.1 Contribution to the body of knowledge

This research addresses the lack of empirical studies on the application of IoT technologies in the LMD industry in Durban, South Africa. By studying the factors influencing cost and quality efficiency, the research provides valuable insights for logistics companies in South Africa to develop strategies for adopting innovative technologies to improve cost and quality management. This not only helps them become innovation-based logistics service providers but also promotes sustainability. The study contributes to the logistics industry and the broader field of Supply Chain Management. Additionally, it extends knowledge and understanding of the application of IoT technologies in LMD companies, providing more literature on IoT technologies and business performance in the LMD sector of the Supply Chain. This work advances understanding in an under-researched context and provides a detailed framework for applying IoT technologies in the LMD sector in Durban, South Africa, and other developing economies worldwide.

5.4 Implications of the study

5.4.1 Managerial implications

To survive and succeed, LMD companies must embrace cutting-edge technologies to effectively reach the market and meet customer demands. Strategies promoting the use of advanced technologies, like IoT, are essential for success. In South Africa's reduced consumer spending power, a viable option for businesses is adopting a low-cost leadership strategy without compromising quality. The adoption of contemporary perspectives in strategy formulation, with IoT technologies as a driver for agility holds promise for helping last-mile businesses achieve competitiveness and sustainability.

5.4.2 Policy implications

The study recommends that the South African government should adopt policies that support technology use in logistics companies through strategic management and financial backing. Moreover, allocating resources to address other critical needs, such as infrastructure development (roads, electricity, and internet bandwidth), is vital, as these challenges often hinder progress. To enhance the SME sector, the government should prioritise providing managerial and technical skills to SMEs.

5.5 Future research

This study offers valuable insights into IoT's potential to improve last-mile distribution systems in South Africa, with a specific focus on the influence of IoT on the cost and quality of the LMD sector. However, there are opportunities for future research to explore additional dimensions and aspects of IoT integration in last-mile logistics, including risk management, environmental impact and sustainability, Regulatory and legal implications, customer experience and comparative studies. By addressing these areas of research scholars would expand the knowledge and understanding of how IoT technologies can transform and optimise last-mile logistics, ultimately leading to more efficient and customer-centric delivery systems.

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Standards of Value Stream Mapping as a tool supporting logistics processes in the healthcare system in Poland
Jolanta Korkosz - Gebska, Lukasz Poplawski

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Standards of Value Stream Mapping as a tool supporting logistics processes in the healthcare system in Poland

Jolanta Korkosz - Gebska
Warsaw University of Technology, 86 Narbutta Street, 02-524 Warsaw, Poland, EU,
jolanta.gebska@pw.edu.pl (corresponding author)
Lukasz Poplawski
Cracow University of Economics, 27 Rakowicka Street, 31-510 Cracow, Poland, EU,
lukasz.poplawski@uek.krakow.pl

Keywords: Value Stream Mapping, healthcare, logistics processes, standard, stroke.
Abstract: According to the World Health Organisation (WHO) a health system consists of many components like organizations, institutions, resources, and people whose primary purpose is to improve health. The system is complex and requires staff, funds, information, supplies, transport, communications and overall guidance and direction to function properly. These elements interact with each other and, as in the logistics system, there are uninterrupted physical, decision-making and information flows between its most important elements, which include: service providers, service recipients (patients), a payer (the National Health Fund), control and supervision institutions, the Ministry of Health. The Polish healthcare system is struggling with many problems, such as insufficient access to health services, inefficient system management, shortages of medical staff, or underfunding. The use of Value Stream Mapping (VSM) standards can significantly contribute to the improvement of logistics processes of the Polish healthcare system. The standards can be also used to improve the processes of treatment of other diseases, but also the functioning of healthcare units.The aim of the article is to present the possibility of applying Value Stream Mapping standards in the process of ischemic stroke treatment as the results of the project 'Lean Management in Healthcare', implemented by the consortium consisting of the Medical University of Warsaw, the Institute of Psychiatry and Neurology in Warsaw and the Polish Society of Health Economics, financed by the National Centre for Research and Development under contract no. IS-2/200/NCBR/2015.

1 Introduction

A healthcare system consists of all organizations, institutions, resources, and people whose primary purpose is to improve health by delivering preventive, promotive, curative, and rehabilitative interventions [1]. 'Healthcare is categorized as a service sector, where service in the form of medical aid is provided. It is very important to rigorously upgrade the healthcare system, in terms of efficiency and productivity. As the healthcare is not just merely a business, but a system which has an impact on all lives' [2].

Logistics activities are complicated particularly in hospitals due to the number and complexity of organizational (administration, hospital wards, outpatient clinics, laboratories, hospital pharmacy, sterilization, etc.) and functional (wide range and number of services provided) logistics processes [3].

Due to the large number of existing medical technologies (over 100,000), health care is one of the most complex spheres of the economy [4]. The demand for medical services far exceeds the ability to finance them, and to some extent even satisfy them, due to the fact that modern civilization contributes to the increase in the number of diseases at a faster rate than it is able to keep up with their treatment [4].

According to the 'Results of the nationwide debate on the directions of changes in healthcare, the main challenges faced by the Polish healthcare system include [5]:

- Insufficient access to health services, in particular to specialist doctors, including health inequalities based on socio-economic status and place of residence;
- Inefficient management of the system at all its levels with a lack of coordination between its individual sectors: primary healthcare, outpatient specialist care, hospitals, rehabilitation, long-term care and social care;
- Staff shortages of medical staff and an inadequate model of competence in medical professions and uneven distribution of medical staff;
- Insufficient activities in the field of public health, disease prevention and insufficient involvement of Poles in their own health;
- Underfunding of the healthcare system;
- Insufficient access to innovations in healthcare, including modern therapies;
- Lack of a long-term, coherent and evolutionary vision for the reconstruction of the healthcare system.

The problems identified in the Polish healthcare system indicate the need to look for alternative ways to increase the efficiency of the system, in the face of its long-term underfunding in relation to the ability to meet the health needs of the society [6].

Stroke is currently a major social problem, as it is the third most common cause of death and the main cause of permanent disability [7]. Annually, 15 million people

worldwide suffer a stroke, 5 million die and another 5 million are left permanently disabled, placing a burden on family and community [8]. Stroke is uncommon in people under 40 years, however, also occurs also in about 8% of children with sickle cell disease [8]. In the acute phase of ischemic stroke, two methods of causal treatment are currently recommended: intravenous thrombolytic therapy with recombinant tissue plasminogen activator (rt-PA) and mechanical thrombectomy involving mechanical removal of the clot from the lumen of the cerebral vessel [9].

Time is of the essence when treating a stroke, which confirms the popular statement 'time is brain' (referring to the famous Benjamin Franklin's original aphorism "time is money"), because with each moment that a stroke goes untreated, the nervous tissue in the brain is rapidly and irreversibly damaged [10]. 'Time that the brain does not receive oxygen determines the extent of the brain damage: the shorter the time the less the permanent damage and the longer the time the more permanent or residual brain damage. Thus, treatment is aimed at getting the patient to a hospital and into a stroke treatment protocol as soon as possible' [11]. For this reason, improving the treatment of patients with a stroke is so important.

One of these ways is to optimize the logistics processes that play a key role in ensuring appropriate patient care. Improvements of the logistic processes can reduce healthcare costs and provide better support for clinical processes [12]. One of the main goals of logistics in healthcare is to search for methods that shorten the waiting time and increase the availability of medical procedures that reduce the cost of treatment [2].

The Chartered Institute of Logistics & Transport (UK) defines 7 Rights of Logistics as:

- getting the **Right** product,
- in the **Right** quantity,
- in the **Right** condition,
- at the **Right** place,
- at the **Right** time,
- to the **Right** customer,
- at the **Right** price [13].

These rights are particularly important in the treatment of ischemic stroke, in which a crucial issue is the reaction time and medicating, that have a great impact on the state of health and even life of the patient. Streamlining logistics processes in the treatment of patients with a stroke is possible thanks to the usage of the lean management concept and its tools, such as Value Stream Mapping (VSM).

2 Literature review

The term 'lean' was first applied by John F. Krafcik in 1988 to explain the Japanese system of success and later spread by James P. Womak, Daniel T. Jones and Daniel Ross in their leading book 'The Machine that changed the world' [14]. In their research, they found that the term 'lean' best describes a system that operates on half of its usual resources (space, labor, capital investment, inventory) and has far less than half of accidents and defective products [15]. There are five principles of lean [16]:

- Identify value from the customer's perspective;
- Identify the value stream for each product or service and address all wasteful steps;
- Make the product or service flow continuously and standardise processes around best practice;
- Introduce 'pull' between all steps where continuous flow is impossible;
- Manage towards perfection.

Initially, the lean system developed mainly in the automotive industry, but over the years it has also spread to other areas, including the healthcare sector. According to J. F. Krafcik: 'lean plants are more capable of simultaneously achieving high levels of productivity, quality, and mix complexity' [17]. 'Lean brings benefits for organizations to be more competitive, as it creates value for customers by eliminating all waste from activities and obtaining lean processes with high economic efficiency' [18]. Waste in the healthcare system is no different from waste in manufacturig systems and includes any expenditure of time or resources that does not cotribute to the efficient delivery of quality healthcare to the patient [19]. There are eigth types of waste in a healthcare system [15]:

- Defects (deficiencies and errors), e.g. time spent not doing something right the first time, checks and fixes for errors, and deficiencies caused by lack of tools, equipment, or lack of availability;
- Overproduction (doing more than patients need or taking action too early);
- Transportation (unnecessary movement of patients and products in the system like samples, materials, instruments, devices, apparatus, etc.);
- Waiting (e.g. for the next action, study, decision, or resources necessary for action);
- Inventory (excess stockpiles resulting in frozen financial resources, expired medications and additional disposal costs);
- Motion (unnecessary employee movements and processing);
- (Over)Processing (doing work that is of no value to the patient and other employees);
- Human potential (waste and losses resulting from not engaging employees with knowledge and potential for improvement, ignoring their ideas, not caring about their development).

The healthcare system is not a manufacturing plant but 'a sociotechnical system in which the technical system is closely interrelated to a social system of people and organisation' [20]. Lean manufacturing methodology could be used in healthcare logistics for solving problems and improving its global performance [21].

The application of lean to the treatment of patients is an attempt to eliminate all forms of waste, without undermining any clinically important steps [22].

According to Al-Balushi et al. [23] factors that are important for the successful application of 'lean' in healthcare include:

- Strong leadership team's support for lean;
- Identifying lean with the strategic agenda of the healthcare setting;
- Understanding what value and customer groups exist in healthcare;
- Undertaking the end-to-end process view to identify and eliminate waste;
- Personnel training and involvement in lean principles and methods;
- Measurement and reward systems aligned to lean objectives;
- Matching demand and capacity levels to improve flow.

Lean has many essential tools that can help organize tasks and improve processes [24]. One of them is Value Stream Mapping (VSM), which is particularly important for the identification and elimination of waste. It helps to visualize the patient's path, understand the entire process of medical treatment which can be later simplified by removing delay, unnecessary movements, consultations or other appointments, and the need for remedial clinical intervention [22]. Delay is the most serious problem in service medical provision, especially in in the treatment of patients with a stroke.

3 Methodology

The originator and initiator of the project, resulted in the described standards, was the Polish Society of Health Economics, which was the leader of a consortium whose members also included the Medical University of Warsaw and the Institute of Psychiatry and Neurology in Warsaw, specializing in the development of new methods of treatment and rehabilitation of patients with mental and neurological disorders.

The development of the standards was possible primarily thanks to the involvement of healthcare facilities, which provided both substantive and practical support in the field of mapping the treatment processes of stroke patients and providing information about them. These were the following facilities:

1. Institute of Psychiatry and Neurology in Warsaw,
2. Mazovian Specialist Hospital in Radom,
3. Mazovian Provincial Hospital in Siedlce,
4. Mazovian Brodnowski Hospital in Warsaw,
5. Mazovian Hospital in Plock.

The map of the current state and the map of the future state for the purposes of the standards were developed based on the analysis of the treatment process of patients with ischemic stroke in the 2nd Neurological Clinic at the Institute of Psychiatry and Neurology in Warsaw as a model unit for the analyzed process [6]. Research methods such as unstructured interviewing and participant observation were used to develop the VSM standards. In the study the desk research technique with two types of sources of information were used: primary (including e.g. data made available by medical facilities) and secondary, which include scientific publications, press articles from trade journals and statistical data obtained from online publications**.**

4 Result and discussion

The concept of developing VSM standards was based on the DMAIC (Define, Measure, Analyse, Improve, Control) method, according to which the following procedures were identified [6]:

1. Identification and selection of the value stream (selection of the VSM process),
2. Map of the current state,
3. Analysis of data of the current state map,
4. Future state map and implementation,
5. Evaluation of implementation effects and continuous improvement.

The standard, as the basis for any activities aimed at improving the current state, requires a process approach. The process mapping technique is one of the specialized tools enabling process identification, necessary for the effective and efficient operation of an entity from the healthcare sector [6]. Due to the fact that healthcare professionals are accustomed to follow instructions, the VSM standards have been prepared in accordance with the principles of rules for creating procedures. Procedures can be defined as an established way of carrying out an action or process defining rules in a specific area of the organization's operation, responsibility for activities and conditions for their supervision. They also specify the types of input documents (to be taken into account by the actions regulated by the procedure) and output documents (to be taken into account by the activities described by the procedure) [25]. The design of the procedure should ensure its transparency and ease of application [25] that is why the VSM standards described the procedures with the following elements:

1. Title.
2. Purpose (What does the procedure regulate?).
3. Scope (Which activities, processes, resources, etc. the procedure is related to?).
4. Liability and rights.
5. Description of the activities (at a relatively general level, with reference to operational documents, e.g. instructions, templates; it is advisable to use graphical forms of notation, e.g. in the form of a flowchart).
6. Records (documents in which the results of the actions indicated in the procedure are recorded).
7. Attachments.

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Each procedure contains a process diagram. As an example, Figure 1 shows a diagram for creating a map of the current state, while Figure 2 shows a diagram for creating a map of the future state and implementation.

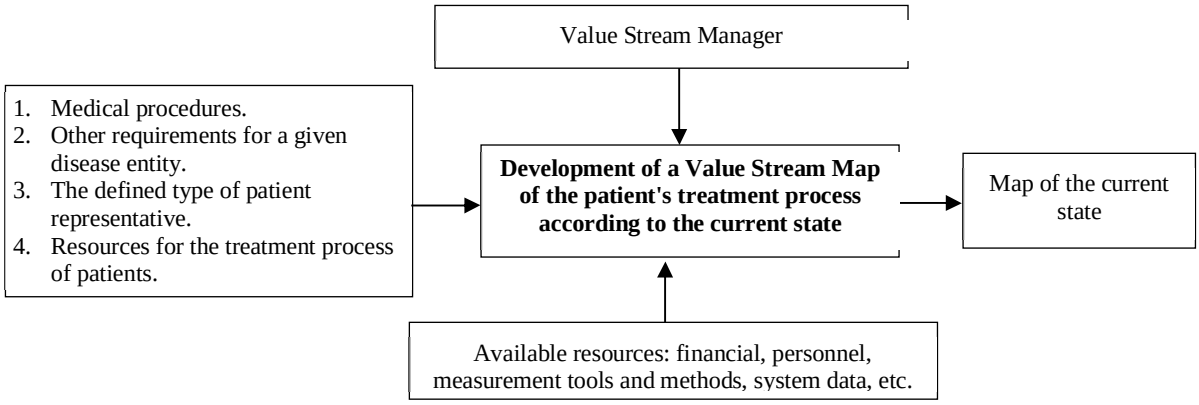

Figure 1 Diagram for creating a map of the current state [6]

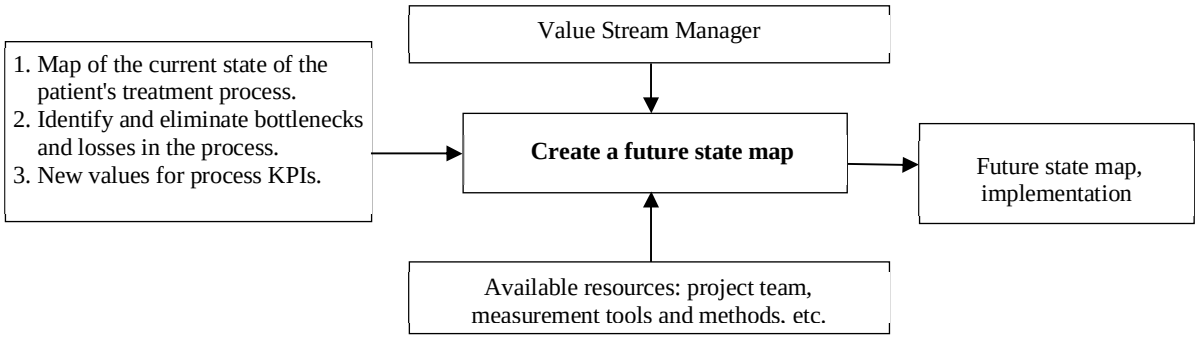

Figure 2 Diagram for creating a future state map and implementation [6]

While creating a map of the current state it is advisable to involve representatives of all departments and organizational units participating in a given value stream in order to correctly identify the path of the patient flow, activities in the process, bottlenecks and potential losses and improvements. The development of a map of the current value stream is aimed at a graphical representation of the treatment process of a representative patient with a stroke and the basic indicators of the value stream. The value stream includes the analysis of patient treatment processes within the scope specified by the value stream manager. The development of a map of the current state begins with the detailed identification of the selected value stream according to the flow of a specific type of patients entering the healthcare facility, i.e. according to the International Classification of Diseases (ICD-9 and ICD-10), which appear at the beginning of the value stream. Defining the type of patient according to these classifications allows to collect the system data and should be done within the framework of Standard No. 1 (identification and selection of the value stream). On this basis, the starting and ending points of the analyzed process of the current value stream state should be defined. Both maps (of the current and future states) are divided into 7 analytical areas reflecting the parameters and indicators of each stage of the patient's stay process and the course of treatment and the patient's stay in individual places where services are provided. The maps should be laid out in such a way that it can accommodate indicators and visualization of processes taking place in the area of basic and auxiliary processes. The maps should include following areas [6]:

1. The area of the patient's health quality indicator.
2. The area of auxiliary processes.
3. The area of basic processes.
4. The area of key parameters of the value stream.
5. The area of registration the patient's stay time in individual place of performance of basic services.
6. Value stream cost area.
7. Summary area of indicators for a periodic value stream (e.g. 1 year).

The area of the patient's health quality indicators graphically reflects the patient's current state of health according to the adopted classification (Rankin Scale or National Institutes of Health Stroke Scale - NIHSS) at a given stage of treatment according to the available data. The indicator should be based on system data or patient history cards over time.

The area of auxiliary processes graphically reflects the places and types of activities performed during the patient's treatment process, where the patient (as a rule) does not reside, where resources are prepared, auxiliary and diagnostic tests are performed, results required in the process are developed, which are then provided in the area

of places where basic services are performed. In this area, it is necessary to identify the activities and resources necessary for the preparation of services, which are the subject of subsequent provision at the places where the basic services are performed, and to estimate them in a temporal and quantitative manner and to identify the frequency of their provision.

The area of (essential) basic processes graphically reflects the chronological identification of places on the diagnostic and therapeutic path, where the patient stays and where auxiliary and essential services are provided as part of the basic treatment processes. In this area, it is necessary to identify the activities and resources necessary for the provision of services and to estimate them in a temporal and quantitative manner, as well as to identify the frequency of their provision.

The area of key parameters of the value stream graphically reflects the resource ratios for individual places of service. It should be developed on the basis of data obtained during the patient's diagnostic and therapeutic pathway and on the basis of data on the availability and use of resources time. In this area the resources (and the number of them) required to serve the patient representative subject to the Value Stream Mapping should be defined.

The area of recording the patient's residence time in each location graphically reflects the chronological identification of the patient's residence time in each location with an estimate of the time spent on [26]:

- VA (value added)- treatment activities that increase value in the process,
- NVA (not value added) - activities related to the process, which do not add value to the treatment process, where:
- VA is the time of treatment and activities closely related to the patient reflected on the PT (Processing Time) line of the graph for a given place of the patient's presence,
- NVA is the waiting time in the process and the transport time - WT/TT – (Waiting Time /Transport Time) reflected on the WT/TT line of the graph for a given location,
- CT (Calendar Time) reflects the length of the patient's stay in a healthcare facility.

The value stream cost area in the form of a graph shows the costs of treating a patient with a stroke at different stages of the treatment process. It is the cost of the treatment process of a single representative patient (unit cost) with separate costs of individual cost components such as all resources (personnel, apparatus, premises, equipment), medical and non-medical supplies, medicines, meals, costs of external services and overhead, departmental, administrative and board costs assigned to the patient (so-called "hotel costs", surcharges, etc.).

The summary area of the current status map indicators in the form of a graph presents the summary selected and most important value stream indicators reflecting the patient stream according to the patient-representative pathway. The data source for the summary of the indicators is the annual aggregated data of the key parameters of the treatment process, time, patient health index and value stream costs. It is recommended to use the most important indicators that describe the value stream, such as the total cost of the representative's patient value stream, an indicator of the effect of treatment of patients appearing at the end of the treatment process, an indicator of the percentage of VA time to total LT treatment time.

The development of a visualization of the treatment process of the representative patient required a physical passage through the patient's diagnostic and therapeutic path, i.e. through all the places where services are provided (the so-called Gemba Walk). During the walk, it was necessary to identify: places where services are provided and prepared, the process of patient displacement, activities and their sequences, resources used in the process and assigning them to activities, external services provided to the patient, information flow process, potential losses and bottlenecks in the process, deviations in resources and processes from the standard treatment process [6].

Any identification should also include the determinants of the process diagnosed as deviations from the patient's standard path. The scope of deviations should include: places where services are provided, services provided, human and material resources and the number of resources required for given activities, activities carried out in each place with the use of devices, apparatuses and instruments, devices, apparatus and instruments, duration of activities in each place, necessary to safely serve the patient representative [6]. All these parameters can be optimized and affect the quality of the logistics of the patient's treatment process.

An example of a future state Value Stream Map together with described indicators of the treatment process of patients with ischemic stroke is shown in the Figure 3.

Standards of Value Stream Mapping as a tool supporting logistics processes in the healthcare system in Poland

Jolanta Korkosz - Gebska, Lukasz Poplawski

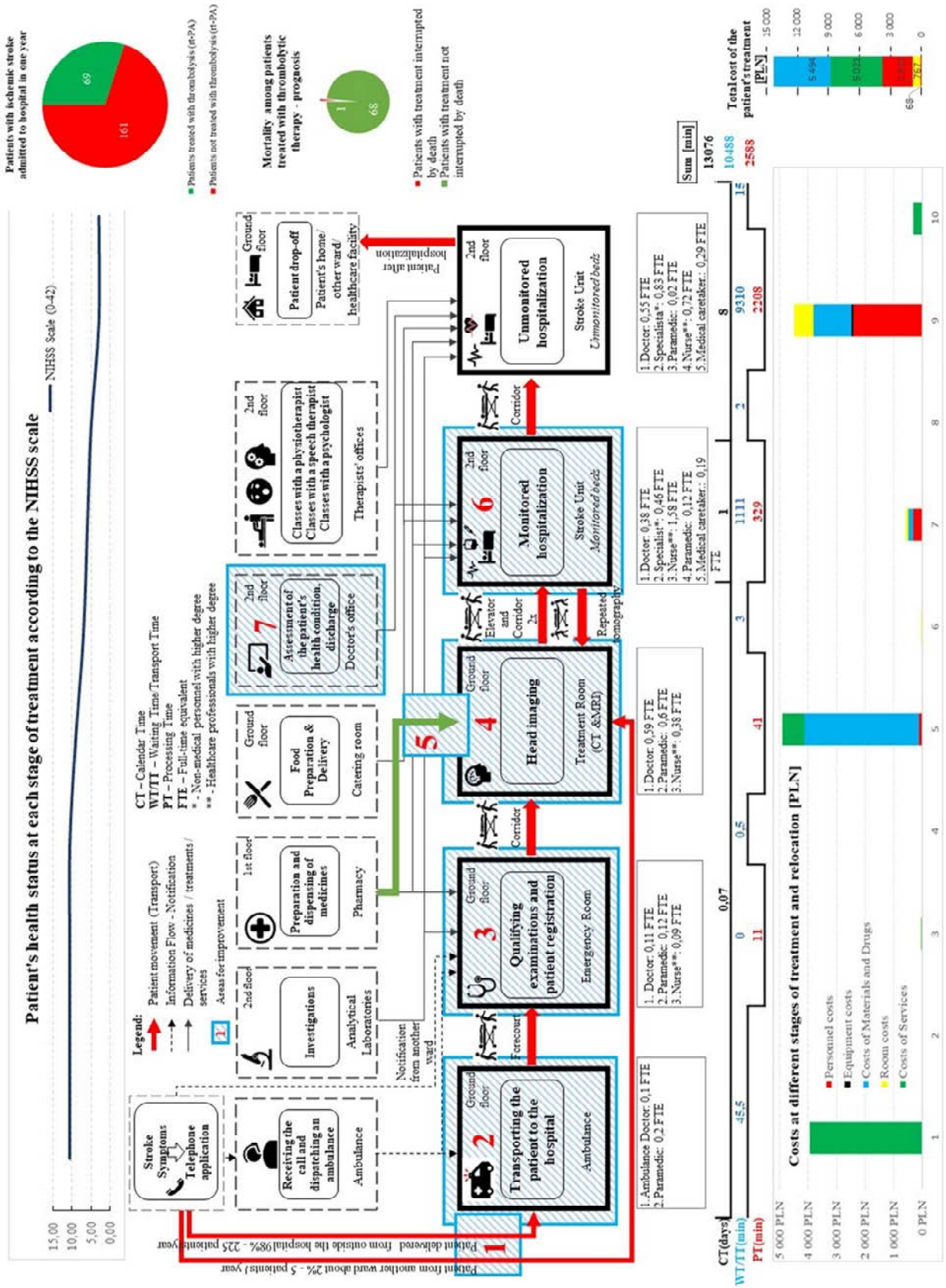

Figure 3 The example of the future state Value Stream Map of a treatment process of patients with an ischemic stroke [6]

An example of a future state map of the value stream of the treatment process of patients with ischemic stroke is shown in the Figure 3 which highlights areas where improvements in the treatment of thrombolysis stroke patients are proposed. Places of improvement were marked on the map in red with sequential ordinal numbers.

In the area no. 1 on the map of the future state, an improvement was proposed consisting in the removal of the barrier and the station serving it at the entrance, while equipping the ambulance with a remote control or a system for remote opening of the barrier, which will translate into a reduction in the time of entry of the ambulance into the premises of the healthcare facility by approx. 0.5 minutes. and reduce security costs.

In the area no. 2 of the future map, an improvement was proposed to record patient data at the stroke site or during transportation, via electronic devices for remote and automatic transfer to the emergency room system. The improvement will reduce the time needed to register the patient, enter data on symptoms and health status by approx. 2.5 minutes, and at the same time avoid errors when transcribing from paper forms.

In area no. 3 on the map, an improvement has been proposed, consisting of:

- moving the qualifying examination room from the lesion area no. 2 to 4, closer to the CT and MRI room, which will translate into a reduction in the time of patient transportation to the examination by approx. 2 minutes and, at the same time, an increase in the efficiency of the use of staff time and a reduction in the costs of resources involved in the patient's transfer,
- the use of beds with the ability to measure the patient's weight in the emergency room will allow for more precise selection of drug doses according to medical procedures proportionally to a body weight, which in the case of a thrombolytic drug is very important due to its high cost and may allow to reduce the cost of drug consumption,
- the use of a wider door in the ambulance driveway, which will make it easier to manoeuvre the bed with the patient and introduce them to the emergency Room.

In the area no. 4 to be improved on the future state map, the following changes have been proposed:

- extension of the patient registration function to include registration functions performed in the emergency Room, thanks to which the registrar's workplace in the additional admission room will be eliminated and the use of human resources in the field of registration functions will be increased,
- creating an emergency room closer to the CT and MRI room, which will reduce the transportation time of the patient approx. 2 minutes,
- earlier blood tests with portable devices performed in the emergency room, rather than in a monitored hospitalization room, which will shorten the diagnostic time.

In the area no. 5 on the future state map, an improvement has been proposed to ensure the possibility of administering a thrombolytic drug in a computed tomography or MRI room, where a diagnosis is made and a decision is made to administer the drug, which will result in:

- shortening the time from the correct diagnosis to the administration of the drug as a result of the shift in the process of moving the patient from the ground floor to the second floor and the time necessary for additional related activities by approx. 5 minutes for the next stage of treatment,
- start of thrombolytic drug preparation approx. 2 minutes earlier,
- the possibility of reducing the stocks of expensive thrombolytic drugs by approx. 50% as a result of eliminating stocks in the monitored rooms of both clinics (the analyzed healthcare unit has two neurological clinics treating patients with a stroke) and accumulating the necessary supply in one place where the drug is administered to patients who are later admitted to both clinics of the facility; the limitation may also apply to other drugs necessary to be administered at this stage of treatment,
- reduction of stocks of expensive thrombolytic drugs in both clinics, contributing to the reduction of drug losses resulting from expired and non-use of full doses by packaging units,
- reducing the time spent on rehabilitation and stay by about 10%.

In the area no. 6 on the future state map, an improvement was proposed to eliminate the thrombolytic drug supply from the handy first aid kit as a result of moving the drug administration site to the MRI site.

In the area no. 7 on the map of the future state, an improvement was proposed consisting in shortening the time spent on contact with the patient's family and explaining the causes, symptoms, path of further treatment and prevention after leaving the healthcare facility, by making leaflets devoted to the subject of stroke available in the healthcare facility in order to reduce the number of questions from the family and the time spent on explanations by the attending physician by approx. 10 minutes during the first visit and next by approx. 5 min.

It has been proposed to introduce continuity of registration of patients' health at every stage on each day of the patient's stay in a healthcare facility in order to better select resources and means, control and verify the medical actions taken.

An improvement has been proposed, consisting in the performance of activities by personnel with adequate and sufficient education to perform given activities in order to reduce the work of resources with a higher rate of labor cost by involving employees such as medical secretaries,

who can perform activities related to fill in the certain documentation for a neurologist.

It was observed that there was a need to make improvements consisting in shortening the time at the first stage of the process, i.e. diagnosing a stroke outside a healthcare facility and transporting patients to it in the so-called 'time window' of 4.5 hours for ischemic stroke. In this area, it is proposed to increase public awareness of stroke prevention and recognition of the early symptoms of each type of stroke through social campaigns about the role of the nearest environment in improving the whole treatment process by reporting this fact and calling the ambulance immediately.

The above-mentioned proposed improvements may contribute primarily to the improvement of the patient's health as a result of earlier administration of the drug and thus less cost-intensive further hospitalization, shortening the time of stay in the facility, improving the efficiency of the facility's resources and reducing the indirect costs of the patient's further functioning in society, which were not measured.

5 Conclusions

The use of lean management tools is still not very popular in improving patient treatment processes in Poland, even though there are many examples of the positive impact of lean concept implementation on the development of hospitals around the world, as below [15]:

- Reduce total clinical trial time by 60% without increasing staffing or purchasing new equipment (Alegent Health Hospital);
- More than 70% reduction in instrument decontamination and sterilization cycle times (Kingston General Hospital);
- Reducing patient waiting times for orthopaedic procedures from 14 weeks to 31 hours (ThedaCare Hospital);
- 95% reduction in patient deaths due to bloodstream infections (Allegheny Hospital);
- Reduced hospital stay by 29% and avoided a huge investment in a new emergency department building (Avera McKennan Hospital);
- Increase revenue from surgical procedures (Ohio Health Hospital) and savings, invested then in improving healthcare through improvement workshops (Park Nicollet Health Services Hospital).

The standards were developed in close cooperation with representatives of the medical community, and their final version was reviewed and approved by the National Consultant for Neurology. In the opinion of Polish scientists dealing with the application of the lean management concept in healthcare, the project under which the analyzed standards were created was very important for the Polish healthcare system [27].

The adaptation of the presented method described in the standards may prove to be very useful from a technological, organizational and economic point of view, in a very wide and diverse range of medical procedures.

The main goal of the described standards was to achieve effects in various areas of treatment and functioning of healthcare facilities. There are mainly four types of effects [6]:

- Procedural, directly related to the medical procedure (in this case, it concerns the treatment of patients with ischemic stroke).
- Medical (technological), related to learning about the shortcomings of medical procedures.
- Organizational, related to the organization of the full process of preparation for treatment, treatment and rehabilitation stage.
- Economic, related to alternative methods of treatment from the point of view of costs and time savings, expressed in the form of costs.

The article shows that the described VSM standards can support logistics processes in the treatment of patients with ischemic stroke, where time saving is particularly important as it increases the chance of returning to the patient's normal life and reversing the effects of the stroke. The standards can be also implemented in treatment of patients with other diseases. The scope of application of the standards in healthcare can be very wide. It results from the high adaptability of the method, expressed on three levels [6]:

- Process, expressed in terms of different configurations of nodes with variable (flexible) time and cost parameters;
- Technological, expressed in terms of different levels of permissible deviations of individual structural elements of medical processes;
- Organizational, expressed through various adaptation activities at different structural points of the organization of the holistic treatment process.

Thanks to the above-mentioned objectives, the adaptation of the presented method described in these standards may prove to be very useful from many points of view in a very wide and diverse range of medical procedures, because a standard is a tool that allows for replicating an effective remedy for anyone who acts in similar circumstances [28].

The use of the developed standards is also associated with the introduction of changes in the health care facility, which is a complex issue not only from the organizational point of view, but also for psychological and sociological reasons, which were not the subject of research discussed in the whole project. Particularly important are the changes that transform the organizational situation of an individual and a team into an innovative situation, very often interpreted as disruptive and threatening to the individual. Reference visits to hospitals allowed us to observe scientifically interesting problems and phenomena that may become the subject of further research, which is a

continuation of this project. The presented standards were used in a few Polish hospitals and can be an important tool supporting logistics processes in the whole healthcare sector.

The application of the lean management concept in the Polish healthcare system needs to be popularized, because despite numerous foreign examples of its use in order to eliminate waste and maximize the savings of resources and the quality of services provided, in Poland it is still a new issue that is used by only a few medical units or hospitals.

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Digitalization, innovation and marketing in logistics
Hassan Ali Al-Ababneh, Mahmud Agel Abu Dalbouh, Salem A. S. Alrhaimi, Ibrahim Mahmoud Siam, Tatyana Ibragimkhalilova

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Digitalization, innovation and marketing in logistics

Hassan Ali Al-Ababneh
Irbid National University, Faculty of Administrative and Financial Sciences - E-Marketing and Social Communication, PO Box 2600, Irbid, Jordan, hassan_ababneh@inu.edu.jo (corresponding author)
Mahmud Agel Abu Dalbouh
Irbid National University, Faculty of Administrative and Financial Sciences - E-Marketing and Social Communication, PO Box 2600, Irbid, Jordan, M_agel_dlb@inu.edu.jo
Salem A. S. Alrhaimi
Sharjah Police Science Academy, Business Administration, P.O Box 29, 31 Block F Street, Sharjah - 2GIS, United Arab Emirates, 32223, salrhaimi@ps.ac.ae
Ibrahim Mahmoud Siam
Irbid National University, Faculty of Administrative and Financial Sciences, Entrepreneurship, PO Box 2600, Irbid, Jordan, I.Siam@inu.edu.jo
Tatyana Ibragimkhalilova
Donetsk National University, Faculty of Economics, Department - Marketing and Logistics, Universitetskaya Street 24, Donetsk, 283001, Ukraine, itv2106@mail.ru

Keywords: digitalization, innovation, marketing, logistics, efficiency.
Abstract: Global digitalization has caused a modification of the modern world market and the adaptation of business strategies of modern companies. The target of the research is to define the peculiarities of trends in the evolution of digitalization, innovation in marketing and logistics of modern companies. It is substantiated that the efficiency and competitiveness of a business are constructively related to the implementation of digital innovative technologies in the marketing and logistics system to optimize business processes and reduce management and operating costs. Based on scientific generalization, it is indicated marketing and logistics interaction and specific features of key aspects in influencing competitiveness. Based on structural and logical analysis, revolutionary technologies and innovations in the marketing and logistics system are highlighted for maximum automation of business processes of modern companies, based on which their development trends are determined. The need for a systematic approach to the consideration of marketing and logistics as inseparable elements of the continuous cycle of companies (production-promotion-sales-service-logistics) is put forward. Based on structural and logical analyze peculiarities of the implementation of the marketing logistics system of companies in conditions of digitalization and innovation, which can be applied in the forming a digital marketing strategy and managing the logistics system of companies in the long term.

1 Introduction

Modern business trends necessitate a flexible and adaptive approach to company management, which is the key to its effective operation in a highly volatile and uncertain environment. Global processes of digitalization and innovation in all areas of company activity, which are characterized by the ability to ensure competitiveness in world markets while maintaining their positions and improving them in the future. However, as part of maintaining a competitive position, modern companies conceptually need to expand the consumer segment and target audience by intensifying marketing and logistics processes through application of digital technologies and innovations that will ensure the execution of strategic business goals and objectives. The conceptual task of modern marketing is to analyze and consolidate the information received as a necessity for the effective functioning of companies in uncertain conditions. Taking this aspect into account, the issue of optimizing the management of business processes of modern companies through the use of digital technologies and innovations in a marketing-logical system remains relevant and requires detailed study. Because of this, new challenges and tasks are formed in the global system management, which are aimed at developing economic systems, optimizing and improving the marketing and logistics system. The multifunctionality of management decisions in the marketing-logical system greatly complicates the process of information exchange between different systems and leads to increased contradictions between the production and organizational and economic systems. The resolution of the presented contradictions can be carried out by adapting marketing and logistics systems based on the implementation of digital technologies and innovations, which will be studied in more detail in this article.

Ensuring the efficiency of a company's activities in today's highly competitive global markets is characterized by the need to organize a marketing and logistics system in amenably with latest technology conditions and trends supporting strategic business goals and objectives. The company's competitiveness is inextricably linked with an effective marketing-logistics system, which provides the

entire chain of production of goods and services (production-promotion-sales-service-logistics) and requires constant improvement based on digital innovative technologies. Taking into account the peculiarities of the intensity of the application of digital technologies and innovations, as well as the implementation of digital information flows in the concept of modern marketing and logistics, there is an urgent need to study this issue for the future improvement of approaches to management and argumentation of key trends in the evolution of the marketing and logistics system.

The relevance and necessity of the study is due to the fact that the intensity of the implementation of digitalization and innovation processes in the marketing-logistics system of companies requires argumentation of the features of their use, highlighting the relationship and development trends.

To achieve the goal of this study, it is inevitable to conduct a detailed study and analysis of the features in the application of a modern marketing and logistics system; argue the main role of digital technologies and innovations, followed by highlighting the relationship between them, ensuring the efficiency of companies. Because ensuring the efficiency of companies directly depends on the process of strategy formation and is based on versatile officials and trends in the modification of digital innovations in the marketing and logistics system, which requires detailed and in-depth research.

1.1 Review of scientific literature in the field of digitalization, innovation and marketing in logistics

The intensity of global digitalization is expressed by the implementation of digital technologies and innovations in all sectors of the world economy. However, globalization processes of integration into a single superior economic space are forcing the management of modern companies to radically review and improve existing approaches to organizing activities, which must necessarily be based on digital technologies and innovations, since their use can ensure the company's efficiency and achieve your strategic goals and business objectives. Considering the relevance of modernizing the existing management mechanism of modern companies and introducing digital technologies and innovations into the business processes of the marketing and logistics systems of companies, it remains necessary to search for basic scientific approaches and practical recommendations in this area to substantiate key trends and features of their development and subsequent application in long-term planning development. It is important to state that the basis this issue and represent the hypotheses of scientists in the field of digital technologies, innovation and marketing and logistics systems.

Noteworthy is the scientific approach of H. Alzoubi [1], which argues for the conceptual need to improve existing approaches to marketing and logistics of companies. This approach argues that changes to introduce and use new types of consumer goods and services, new production and vehicles, markets and forms of organization in the industry are clearly related to innovation. It should be noted that this approach is specific and aimed at the specifics and characteristics of the industry, and not all areas of company activity, which is essential and significant in modern conditions and can only be considered for companies in this industry, as well as for other forms and types of activity, but it remains unclear The issue of determining the specifics and characteristics of the evolution trends of companies in economic activity segment has been resolved, which requires a more detailed and in-depth study.

The interpretation of the introduction of innovative IT-technologies for the purpose of modifying management objects and ascertaining the economic, social, environmental, scientific and technical effect are considered in the scientific work of P. Adams [2]. This approach is based on studying the influence of technology and innovation on the object of company management, which will allow taking into account these factors when forming the company's strategy, but the essence of digital technologies and innovation and their impact on the marketing and logistics system of modern companies is not disclosed, which requires improving this approach and more detailed study.

Features and changes in the original structure of the production mechanism, the transition of its internal structure to a new state, with regard to products, technology, means of production, professional qualifications of the workforce, organization of logistics and sales; changes that have both positive and negative consequences, both economic and social of the introduction of innovations and advanced technologies are considered in the scientific research of S. Shao [3]. This approach is very interesting and relevant in modern conditions, but this approach justifies the clarification of the features of new technologies and innovations in the internal processes of the company. Based on this, taking into account the tendency in the modification of the global market and the need for business scaling to achieve maximum results, the issue of the need to implement digital technologies and innovations not only for internal but also for external business processes of companies is becoming relevant, which remains unresolved and requires further research.

Focusing on the features of the development and integration of marketing and logistics into a united system, as the basic practice of supply chains in markets in the scientific study of Dadzi K. [4]. This approach argues for the key role and complementary elements of the marketing and logistics system, which are determined by the efficiency of companies in the main markets by building an optimal supply chain. It should be noted that this approach will highlight the main theoretical aspects in the cooperation of marketing and logistics of a company in modern conditions for organizing an effective supply chain, however, the question of key tendency in the evolution of the marketing and logistics system under the

influence of digitalization and innovation remains open, which requires detailed research. Focusing on the fact that in highly competitive global markets there is a constructive relevance in the implementation of digital technologies and innovations in the field of marketing and logistics systems into the activities of companies, we should consider the scientific work of Granstrand O. [5]. This study focuses on an approach that states the process of practical application of innovation and leads to the creation of products and technologies that are better in their properties, focused on economic benefits and additional income, and covers the entire range of activities - from research and development to the marketing and logistics system. This approach is more adapted to modern business realities, but does not reveal the specifics and features of the implementation of digital technologies and innovations in the marketing and logistics system, which requires more detailed research.

Noteworthy is the scientific approach of Dana L. [6], who argues that the final result of creative work is obtained from investing in science and new technologies, in new forms of labor organization, service and management, including forms of control, accounting methods and planning the use of which is aimed at improving economic efficiency. A specific toolkit for entrepreneurs with which they use change as a chance to implement a new type of business or service. The presented concept conceptualizes the features of the use of new technologies and innovations in the performance of companies and their impact on the procedure for assessing impact factors and choosing alternative tools, but taking into account modern tendency in the global digitalization of all spheres of human life. However, the question of the features and specifics of digitalization, innovation in marketing and logistics remains unresolved, which requires a more detailed study. Conceptualizing the above, it should be noted that in modern scientific literature there is no single approach and view on determining the features of the use of digital technologies in the marketing and logistics system of companies, and there is also no justification for the role of digital technologies innovations that generate modern trends, which in turn confirms the relevance and necessity of this research.

1.2 Marketing and logistics: features of interaction and impact on the competitiveness of modern companies

The digitalization of global business is based on the introduction of innovation and causes increased competition, the formation and implementation of a logistics-marketing system and interactions, which is a factor in increasing the efficiency of companies. This is characteristic in that this interaction is the following:

1. Interrelated management concepts (logistics and marketing as a streaming market construct).
2. Logistics is the basis for the application of a marketing is the basis for developing, a logistics strategy and optimizing the logistics system.
3. Tools for achieving and maintaining competitive advantages.

It is important to note that the presented interaction creates new conditions and additional opportunities for increasing the value of the product, service and its offer for the consumer, which increases the degree of his satisfaction with the purchase and determines his readiness to become a regular customer of the company. This is a condition for achieving its competitiveness, increasing the level and strengthening of competitive advantages in the long term, as

well as bringing its strategic potential in line with the conditions of the external environment. The quality and completeness of the modification of logistics and marketing functions have a positive impact on the company's competitiveness in the global market. Marketing parsing determines and specification customer destitution; Logistics tools ensure synchronization turnover flow at the end of the forehanded period redress demand on the basis of exploration marketing. Since its target audience characterizes each market, therefore, the practical issues of ensuring competitiveness through the implementation of digital technologies and innovations should be related to the specific market and the company's ability to:

1. Resist the growing competitive pressure and neutralize the negative effects of an aggressive environment.
2. Return to the initial positive state and maintain their organizational integrity while showing the flexibility of the organizational and managerial structure.
3. To form a holistically dynamic equilibrium system that independently organizes the effective achievement of organizational goals and determines the guidelines for strategic development [7].

Modern business conditions are characterized by the fact that the specific interaction of marketing and logistics business stages in a company represents a wide range of activities that depend on suppliers of raw materials and their delivery to the end consumer, which provides goods or services in accordance with current needs. Logistics is the final element of efficiency, contrary to the relationship between the marketing and logistics systems. It is important to note that this allows us to talk about marketing logistics, as well how to state the logistics aspect of assessing the competitiveness of companies. When discussing the interdependence of marketing and logistics, it is conceptually necessary to emphasize the fact that the presented relationship between flow and market-oriented management concepts underlies marketing logistics - a system of planning (marketing) and organization (logistics) of presenting a product or service of the required quantity and quality according to the level of demand and time-price indicator. Marketing logistics ensures the organization of marketing and the implementation of logistics according to supply and demand. To achieve

consistency and proportionality between supply and demand, it is necessary not only to ensure the movement of commodity, communication and financial flows, but also to predict demand and improve relationships between companies and their counterparties. From the perspective of marketing logistics, the consumer ensures competitiveness. The consumer's perception of the brand determines its competitiveness to the extent of uniqueness and satisfaction of needs according to the gradation of their significance. Focus on the consumer underlies the justification and implementation of the company's competitive advantages, which are determined by the introduction of digital technologies and innovations in the activities of companies. It encourages the creation of customer value, attractiveness and usefulness [8]. Character of logistics in operation becoming and evolution. of a customer-oriented system is great. Since each company, based on the main characteristics, parameters and interests of its target audience, emphasizes its mission and vision for assessing competitiveness, its achievements are impossible without digital technologies and innovations.

The relationship between logistics and marketing of modern companies is a complex and debatable issue. However, given this, it should be noted that there are different points of view: logistics is part of marketing; marketing is part of the logistics; logistics and marketing belong to different areas; logistics and marketing have common areas.

According to many researchers, it is advisable to consider logistics and marketing as independent sciences, activities that have both common and specific areas for each of them [9]. Based on this, the author of the article, based on an in-depth critical analysis of scientific research and scientific generalization, argued that modern marketing and logistics closely complement each other in meeting consumer needs at reasonable costs. The primary functions are marketing, which answers the question “what is needed?”; logistics functions are secondary, it answers the question "how to do it?".

Marketing and logistics are equal parts of the company’s unified sales system for its products. It should be noted that with the immediate implementation of a marketing and logistics system, not only sales efficiency increases, but also the functioning of the company in the ambush of the use of digital technologies and innovations, that designate the relevance of this research.

Noting the considered scientific approaches in the field of modification of marketing, logistics and implementation of digital technologies and innovations, the author of the article structures the key interactions of marketing and logistics companies to ensure competitive advantages in the global market, which are presented in Figure 1.

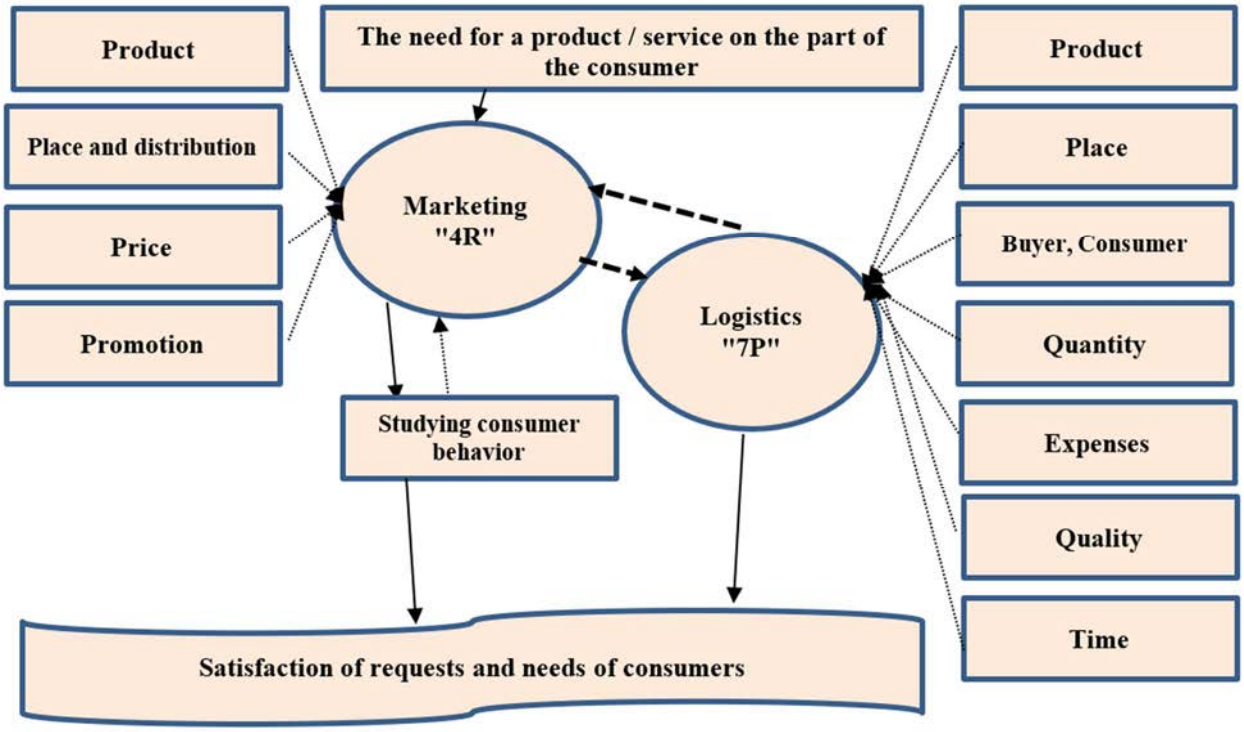

Figure 1 Key interactions between marketing and logistics companies for provision of competitiveness advantages in the global market

Conceptualizing the presented, it should be noted that marketing and logistics are important sources, since their effective operation directly affects the quality of customer service [10]. It is important to understand that the strength of the influence of logistics on the company's competitiveness largely depends on how efficiently and

competently logistics interacts with the company's marketing activities. It is also worth noting that the marketing and logistics concept is not universal for any company and can be diverse, which is determined by the specifics and type of activity of the company. It requires changes and improvement through the implementation of digital technologies and innovations based on the field of activity of each company and its strategic goals and business objectives. Due to the presence of strong competition in the global market, which forces companies to revise existing approaches to organizing activities repeatedly, modern companies must maximize the use of the full marketing and logistics concept. Nevertheless, world practice says that in the near future this approach will become more widespread. This conclusion is also supported by the fact that modern business is forced to exist in conditions of uncertainty and a constantly changing economy, which means that companies are constantly looking for new solutions and ways to strengthen and consolidate their positions in the market, which are possible with the help of modern digital technologies and innovations. Based on the above, we can conclude that logistics and marketing activities are capable of complementarity. At the same time, being implemented synchronously within the framework of the marketing and logistics concept, they establish an effective solution to business problems related to organizing company strategy and achieving business goals. Appliance of marketing tools in logistics system management operations creates most significant and favorable ground for the development of financial stability and economic activity of companies. Thus, it is impossible for companies that develop only marketing or only logistics to achieve a leading position in the modern world market. The growth of profitability and efficiency leads to a constant search for mechanisms based on innovative digital technologies and their constructive infusion into the business of companies. Based on the above, it should be noted that marketing is “planning”, “implementation”, “control” over the physical flows of materials and finished products, from points of origin to points of destination, in order to satisfy consumer needs. Ensuring the efficiency and competitiveness of companies is possible only based on meeting the needs of customers. Marketing allows you to track and determine the demand that has arisen and answers the questions: what product is needed, where, when, in what quantity and what quality. Logistics - provides the physical promotion of the demanded commodity mass to the consumer [11].

Logistics integration allows the delivery of the required product or service to the right place and time at minimal cost. Marketing is aimed at market research, advertising, psychological impact on the buyer and other factors. Logistics, in the first place, is aimed at creating technically and technologically related systems for transporting materials through commodity distribution chains, as well as systems for monitoring their passage. Based on the main results, it should be noted that marketing and logistics communications interweave, which makes it difficult to separate the spheres of interests of business areas. Arguing the presented specific interactions of marketing and logistics and their impact on the competitiveness of modern companies, it is important to state that leadership and competitive positions in the global market today are acquired by those who are competent in the field of logistics and marketing, own your methods, effectively integrate and apply them in practice in the process of company management. However, given the trends in the modification of digitalization and changes in innovation, digital technologies are necessary to optimize the business processes of companies and increase the efficiency of marketing and logistics. The evolution of the digital economy and globalization lead to a radical revision of existing methods and approaches to modern business management, which requires a more detailed study and study of the specifics of digital business transformation, which will highlight the main aspects and its role in the marketing and logistics system.

2 Methodology

Peer review process

To implement the research and determine the features in the development of digitalization, innovation and their implementation in the marketing and logistics systems of companies, various sets of methods and tools were used. The need for this study is determined by the inefficiency of management companies in the global market, which are characterized by high costs of organizing activities and minimal profitability. All this is because the global digitalization of the global economy is characterized by the growth of new technologies and management approaches that are based on innovation and require their application in the marketing and logistics system of companies. To achieve this goal and confirm its relevance, the author of the article conducted a critical analysis of the features of the development of approaches and methods in the field of digitalization and innovation and their implementation in marketing and logistics, and also expressed an opinion on, based on structural and logical resolution, the key aspects of the use of new technologies, such as internal business processes of companies, as well as external ones when interacting with counterparties. Based on a critical resolution of scientific research, it is shown that there is no single approach to organizing an effective marketing and logistics system and identifying key development trends in the context of digitalization and innovation, which confirms the relevance and necessity of this research. Based on structuring and scientific generalization, key approaches to organizing the marketing and logistics system were conceptualized, which made it possible to identify their key interactions to ensure the competitive advantages of modern companies in the global market in current conditions.

Structuring and scientific generalization made it possible to justify the need to use digital technologies and innovations to ensure business efficiency. An analysis of the features of trends in the digital transformation of

modern business made it possible to argue for key trends in development based on a statement of the main digital technologies and innovations being introduced in all sectors of the world economy. This led to the identification of the main directions and most promising niches of digitalization of the world economy. Attention is focused on digital technologies and innovations, which are reflected in the marketing and logistics systems of modern companies. Main excellence and flaws of application digitalization, innovations in the marketing-logistics system of modern business are highlighted. Theoretical hypotheses of the features of interaction between the marketing system and logic have been formed, as well as scientific and practical recommendations for the implementation of digitalization and innovation in the marketing and logistics system of companies, which represent a detailed description of modern trends that can be used in practice in the formation of a company's marketing and logistics system.

3 Result and discussion

Modern market conditions are conditioned by a global digital transformation, which consists in the implementation of methods for the inculcation of digital technologies and innovations in the business processes of companies. Digitalization is used to change and improve business operations, making it scalable, efficient and more profitable.

It is important to state that the transformation digital of business is aimed at improving the quality of customer service using digital technologies and innovations. Not so long ago, the introduction of social networks in the business sphere could be called a revolution, but in modern conditions this is not enough and many companies need modern technologies to improve management methods and brand promotion. With the revolutionary transition from analog to digital business strategies, companies are gaining significant competitive advantages.

However, decisive action is needed, and some of the new processes are launched quickly and efficiently, while others can lead to long-term transformations, and even provoke deterioration in short distances. A rational approach to digital transformation and the introduction of effective tools will help to digitalize the company and expand its opportunities in the global market.

Digital transformation on a global scale is expanding at an intense pace and is characterized by the development of a new phase with the active use of innovation, artificial intelligence, machine learning, remote seating, online assistants and consultants, and many other tools. Digitalization and innovations in the marketing and logistics system are interconnected and ensure the optimization of business stages and increase their efficiency for the company as a whole. Based on this, on the basis of scientific generalization and critical analysis of scientific approaches [12-13], the author substantiates the conceptual impact of digitalization, innovation on marketing and logistics of modern companies, which is shown in Figure 2.

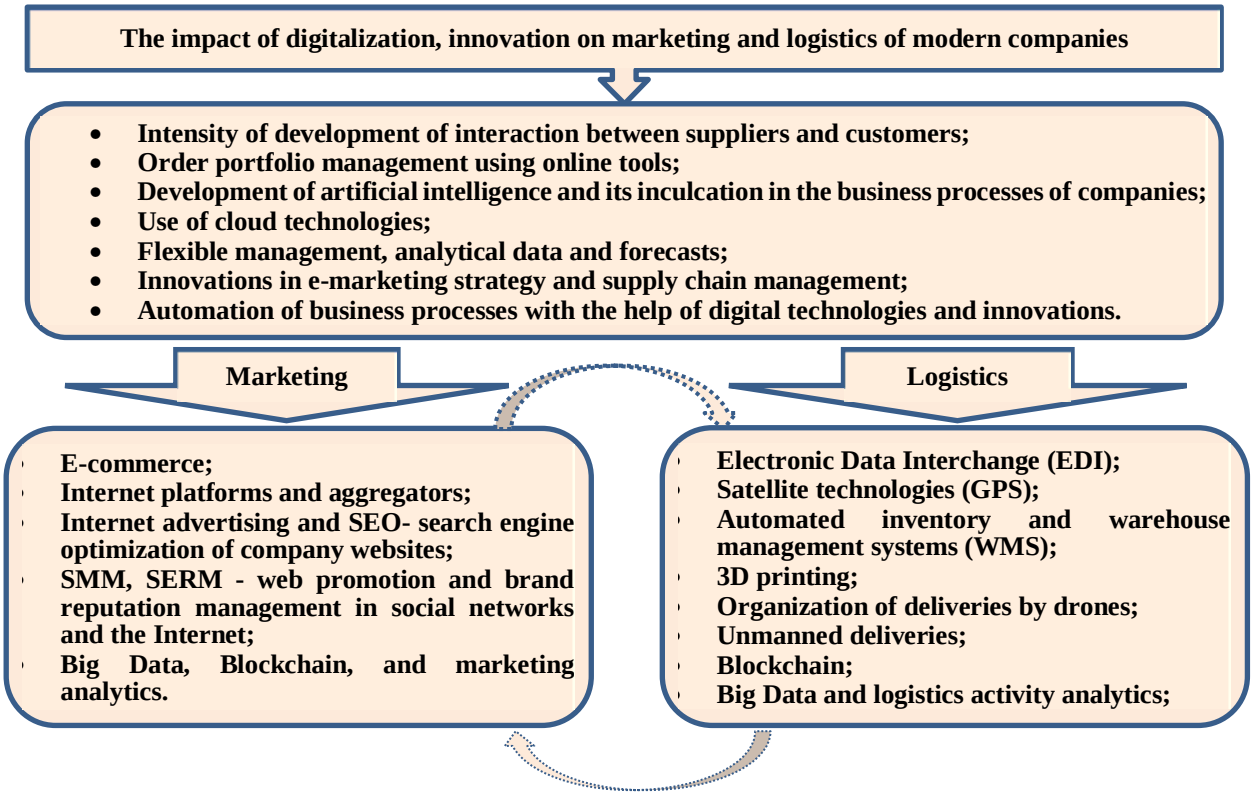

Figure 2 Conceptual impact of digitalization, innovations on marketing and logistics of modern companies

It is important to state that, in contrast to the identification of features of the development and integration of the marketing-logistics system into the basic practice of supply chains in basic markets in scientific research [4], in Figure 2 states that the key task of digitalization and innovation of modern business is to simplify the management process and increase its efficiency by optimizing costs, business processes and automation.

It should be noted that the accentuated influence of digitalization and innovation on the marketing and logistics system of modern companies should be considered in more detail in terms of digital technologies and innovations, which are conceptualized by the author of the study based on an in-depth structural and logical analysis of scientific works and approaches [13-14], which allowed to argue the key ones.

The classification of key digital technologies and innovations in the field of marketing, logistics, their features and characteristics are presented in Table 1.

Focusing on the influence of digitalization and innovation on the marketing and logistics of modern companies, conceptualized by the author of the study, it should be noted that the global modification of digital technologies and their application in marketing and logistics processes largely ensures autonomy, speed accelerates their implementation and reduces the cost of infrastructure and operational components. Financial and analytical planning, inventory and supply chain management, simplifies the process of managing the company as a whole. It is important to state that the greatest effect comes from an integrated approach to the implementation of digitalization and innovation in all business processes of the company from all sides, using all relevant digital tools, means and channels. The presented digital modification affects all sectors and niches of the global economy, including the marketing and logistics systems of current companies.

It should be noted that the digital transformation of modern business is a complex and lengthy process that requires the involvement of specialists, time and financial costs. The argumentation of key business goals under the influence of innovations is highlighted in a scientific study [12], where it is considered that the key drivers of marketing are innovations and information technologies and information flows, but the issue of their comprehensive influence on the marketing and logistics systems of companies, taking into account modern trends, is not addressed, which requires in-depth analysis and conceptualization of the main aspects. Based on this, it should be stated that digitalization and innovation in business ensure the achievement of many strategic business goals of modern companies: 1) Optimization of company costs; 2) Stay ahead of competitors by introducing new technologies and improving the quality of service and products; 3) Leadership positions of the company and formation of the company's brand image; 4) New opportunities for consumers; 5) Improving the efficiency of business processes; 6) High-quality planning of production, logistics and service.

It is important to note that the intensity of the application of digitalization, innovation and their implementation in the marketing and logistics system of current companies hinge from economic evolution of a particular country and company, the general policy of the state and the strategy of the company and the global world market as a whole. Arguing the technologies and innovations classified by the author of the study, their implementation in the marketing and logistics system of modern companies has a significant potential for increasing productivity and, ultimately, raising the standard of living.

Despite the fact that the impact of new technologies and "general purpose" innovations, such as artificial intelligence, block chain, Big Data, on productivity has not yet fully manifested itself in the global space, numerous literary sources demonstrate a positive correlation between the introduction of established digital tools and the performance of companies [15]. Based on the presented, it should be stated that the implementation of digital technologies and innovations in the marketing-logistics system of current companies ensures the intensification of evolution processes and the emergence of new forms and tools for organizing business processes by automating, optimizing and improving them in terms of quality, service and maintenance.

Digital technologies and innovations in marketing determine the development and implementation of renewed forms of web promotion using innovative channels that can increase the reach of the target audience, increase brand awareness on the Internet and significantly increase sales. As for the logistics part of the companies' activities, the cost of production directly depends on it, which occupies a share of about 20 to 60%. To reduce it or increase the competitiveness of the company, you should constantly work on improving the logistics component. The modern global market requires the full provision of the consumer with logistics services and often logistics is transformed into a completely new model, where supply chains are based on digital technologies and innovations.

The implementation of digital technologies and innovations ensures the achievement of a number of strategic business goals: 1) Reducing equipment downtime and increasing production volumes; 2) Acceleration of production design processes and delivery of products to the consumer; 3) Reducing the cost of field testing through the introduction of digital twins and visual modeling tools; 4) Increasing the level of transparency of operations and reducing costs throughout the supply chain management cycle; 5) Reduction of energy losses during technological operations. It should be noted that in the modern conditions of the functioning of companies, the most popular technologies and innovations are wireless communications, artificial intelligence, including computer vision, speech technologies, decision support

systems, and distributed registry systems, virtual or augmented reality solutions.

Table 1 Classification of key digital technologies and innovations in marketing and logistics of modern companies

TECHNOLOGIES AND INNOVATIONS	CHARACTERISTICS OF THE IMPLEMENTATION OF INNOVATION TECHNOLOGIES
MARKETING	
ELECTRONIC COMMERCE	The branch of the digital economy with financial and commercial transactions that are carried out using computer networks, and the processes associated with such transactions.These technologies have found their application in the following industries: electronic information exchange (Electronic Data Interchange, EDI), electronic movement of capital (Electronic Funds Transfer, EFT), electronic commerce (English e-trade), electronic money (e-cash), electronic marketing (e-marketing), electronic banking (e-banking), electronic insurance services (e-insurance).
SEARCH ENGINE OPTIMIZATION	A set of actions to raise the position of the company's website in the results of search engines for certain user requests, in order to increase network traffic (for information resources), potential customers (for commercial resources) and subsequent monetization (revenue generation) of this traffic.
ARTIFICIAL INTELLIGENCE	Technologies that improve marketing strategies and increase conversions based on business acceleration, personalization, machine learning and consumer insights.
SOCIAL MEDIA MARKETING (SMM)	A set of measures to use social media as channels for promoting companies or a brand and solving other business problems of companies in modern conditions.
ADVERTISING (PPC)	An advertising model used in digital marketing in which an advertiser places ads on websites and pays their owners for a user clicking on a placed banner (text or image).
CONTENT MARKETING	A set of marketing techniques based on the creation and / or distribution of information useful to the consumer in order to gain trust and attract potential customers through the implementation of digital technologies: websites, chats, and blogs, video and audio tools.
SEARCH ENGINE REPUTATION MANAGEMENT (SERM)	An approach to organizing a company's strategy that shapes and influences the public perception of the company, individuals, or others on the Internet, which helps shape a positive public opinion about the business, its products, and services.
BLOCKCHAIN	New opportunities for advertisers. Ensuring the protection and privacy of consumer data, the anonymity and independence of transactions available to individual users, gives consumers more control over how, when and with whom they deal. These technologies allow you to ensure a continuous marketing process with your target audience.
BIG DATA	A variety of large volumes of data that are stored on digital media. These include general market statistics and personal data of users: information about transactions and payments, purchases, movements and preferences of the audience.
LOGISTICS	
3D-PRINTING	Additive manufacturing expands the manufacturing process, shortens supply chains by printing products to order and reducing stocks of finished products. Delivery of raw materials by 3D printing logistics companies at delivery points instead of finished products.
INTERNET OF THINGS, (IOT)	An approach to transferring data between physical objects (“things”) that are equipped with built-in mechanisms and technologies for interacting with each other. It is assumed that the company of such networks is able to rebuild processes to minimize human participation.
CLOUD TECHNOLOGIES	Providing high-speed network access, expanding physical resources, infrastructure scale and efficient supply chain management.
ARTIFICIAL INTELLIGENCE	Optimization of internal processes, eliminates the human factor and errors, speeds up work with a partner, helps to quickly get a comprehensive analysis and recommendations for improving the company's logistics processes.
ROBOTIC PROCESS AUTOMATION (RPA)	Business process automation technology based on metaphorical software of robots (bots) or artificial intelligence workers. A distinctive and main feature of RPA robots is the ability to use the user interface to collect data and control applications without human intervention..
AUGMENTED REALITY	Technologies that provide a direct or indirect representation of the real world through elements of computer reality perception.
BLOCKCHAIN	Technologies that allow shared access through the Ethereum network to securely verify document transactions and send cargo to a company's logistics system.

The use of unmanned technologies in e-commerce is also relevant - this is not just a tribute to fashion, but a necessary condition for survival in a highly competitive market. In addition, the e-commerce and logistics market today is faced with a large shortage of personnel, which strengthens the role of these technologies [16].

Also important is the introduction of robots and unmanned technologies, which relate not only to the process of delivering goods and services, but also to the entire logistics chain, which includes sorting and warehousing. Dark stores, which are small warehouse stores that are inaccessible to ordinary customers but are used by market participants to quickly complete orders within the city to organize fast and high-quality logistics, have taken active distribution. Arguing the presented in this study, it should be noted that the intensity of digitalization processes, innovations in marketing and logistics of modern companies in many cases depends on many factors that can stop these processes, namely:

1) Lack of necessary infrastructure. First, the company needs to deal with internal issues and develop a fundamentally new approach to conducting marketing and logistics activities. Infrastructure is the foundation for digital technology and innovation, and without it, digitalization is difficult to achieve.

2) Lack of the necessary budget. Digitization involves an impressive financial investment. Before implementation, the company should analyze its financial capabilities and assess all possible risks.

3) Lack of competencies. The company's staff may have a low level of digital maturity, which is often the reason for rejection of change.

4) Internal objections. Changes in the traditional way of working of the staff are often perceived negatively, especially if the question arises of the need to increase the level of knowledge, skills and abilities. Demonstrating the benefits of digital technologies for staff and learning from successful cases of other organizations. This will help minimize the backlash.

5) The risk of reducing the number of jobs. With digitalization, the risk of unemployment is growing, because many professions are becoming irrelevant due to automation and robotization of processes.

6) Information security risks. It is necessary to think about digital security and take measures against possible hacker attacks and theft of digital data [17-18]. Based on the foregoing, it should be noted that global supply chains are under constant improvement based on the use of digital technologies and innovations. Innovative and technological development in marketing, logistics and transport companies is no longer just a goal, but a necessary condition for survival in the global competitive market. Modern business is at the beginning of a new logistics modification, which is associated with the intensification of digitalization and innovative processes in all areas of company activity, and in the near future - a significant part of companies' business processes will be automated and robotic.

4 Conclusions

Digital transformation of business on a global scale is due to the need to modify approaches and management methods. The study is based on the substantiation of trends in the modification of digitalization, innovations in marketing and logistics of companies that ensure operational efficiency. The processes of global digitalization of all sectors of the world economy are caused by the variability of the external environment and the use of digital technologies and innovations, which optimize operation and their maximum automation. An important element of the study is a systems approach to substantiate the operation of digitalization and innovation of the marketing and logistics system, which represents all stages of the company's functioning.

The results obtained made it possible to achieve the set goal in terms of substantiating the features in digitalization, innovations in marketing and logistics of modern companies based on the use of analysis. The key scientific approaches and foundations for the development of theoretical aspects of the application of digital technologies and innovations into the practical activities of companies are highlighted. Based on critical analysis and scientific generalization, the need to increase attention to the processes of intensity of modification of digital technologies and innovations in all spheres of human life is argued. This led to the conceptualization of key theories and justification for the lack of approaches and methods for applying digital technologies and innovations in the marketing-logistics system, which confirmed the relevance and need for detailed research. A critical analysis of existing approaches to organizing the activities of companies based on the evolution of digital technologies and innovations allowed us to confirm that existing approaches and methods do not correspond to the realities of business functioning and are targeted and non-specialized, depending on the type of the company. Based on this, the author highlights the conceptual relationship of the marketing and logistics system and the features of the application of digital technologies and innovations, which provide a competitive attitude in global market and allow scaling the business, increasing sales and brand awareness.

The key interactions between marketing and logistics of companies to ensure competitive advantages in the global market are identified. This made it possible to formulate the theoretical prerequisites for creating a company strategy in such a way that it is systemic and inseparable from marketing and logistics. The important aspects and features of the modification of digital technologies in the global economy are argued, based on which the main strategic business goals are identified, the achievement of which is possible by the use of digital technologies and innovations in the company's marketing and logistics system. The main directions of development of digital technologies and innovations and their impact on the business processes of modern companies are substantiated. Based on the results obtained by the author, the conceptual impact of digitalization and innovation on

the marketing and logistics system of modern companies is considered. Based on this, the author classifies key digital technologies and innovations in the marketing-logistics of current companies, describes in detail the most popular technologies and innovations depending on the field of application. It is shown that the modification of digital technologies in the world and their application in marketing and logistics processes ensure autonomy, speed up their execution, reduce the cost of infrastructure and operational components, financial and analytical planning, inventory and supply chain management, and also simplify the process of managing the company as a whole. The results of the study and the developed scientific and practical recommendations were applied in the formation of the company's strategy and further planning of its long-term modification, taking into account the introduction of digital technologies and innovations into the marketing-logistics system.

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Profit comparison analysis in production system simulation based on lean principles to achieve sustainable manufacturing
Saiful Mangngenre, A. Besse Riyani Indah, Nadzirah Ikasari Syamsul, Andi Nurwahidah, Muhammad Reza D. Bagus

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Profit comparison analysis in production system simulation based on lean principles to achieve sustainable manufacturing

Saiful Mangngenre
Universitas Hasanuddin, Faculty of Engineering, Department of Industrial Engineering, Jl. Malino No.8 F, Gowa, South Sulawesi, Indonesia, saiful.ti@unhas.ac.id (corresponding author)
A. Besse Riyani Indah
Universitas Hasanuddin, Faculty of Engineering, Department of Industrial Engineering, Jl. Malino No.8 F, Gowa, South Sulawesi, Indonesia, a.besseriyani@unhas.ac.id
Nadzirah Ikasari Syamsul
Universitas Hasanuddin, Faculty of Engineering, Department of Industrial Engineering, Jl. Malino No.8 F, Gowa, South Sulawesi, Indonesia, nadzirah.ikasari@unhas.ac.id
Andi Nurwahidah
Politeknik ATI Makassar, Department of Agro-Industrial Engineering, Jl. Sunu No.220, Makassar, South Sulawesi, Indonesia, Nurwahidah.andi@atim.ac.id
Muhammad Reza D. Bagus
Tokyo Institute of Technology, 2 Chome-12-1 Ookayama, Meguro City, Tokyo 152-8550, Japan, dobagusmuhammadreza@gmail.com

Keywords: production system, lean concept, profit, unit cost, sustainable manufacturing.
Abstract: Companies can achieve effective and efficient process if they make continuous improvements to achieve sustainability. In general, companies are aware of waste in the production process, but do not carry out measurements and analyzes related to this waste, including unit cost and profit analysis. A production system is needed that is able to minimize the unit costs and maximize profits in the company, one of the concepts used is the lean concept. This study aims to analyze the cost unit and profit generated in production systems that apply lean principles. Production system simulation is carried out using the concepts of Heijunka, Jidouka, and Kanban System. These three concepts are applied to a production system simulation that uses miniature cars with unit cost and profit comparison outputs with traditional production systems, pull systems, heijunka, jidouka, and Kanban systems. The results show that the unit cost of simulations 1 to 6 is getting lower, while the profit is increasing. In simulations 1 and 2 no profit was obtained because of implementing the traditional system while in simulations 3 to 6 there was an increase in profit because they had applied lean principles to the production system. Simulations that have implemented the lean concept have low unit costs and increasing profits, but what distinguishes the work methods applied. Production systems that apply the lean concept can help a company achieve sustainability in the economic field.

1 Introduction

Competitionin the industrial world is becoming increasingly stringent with the existence of new innovative manufacturing technologies so that this makes companies able to continue to maintain and improve quality and production capacity [1].

Lean Manufacturing is a concept that is able to identify and eliminate waste through continuous improvement. This method is ideal for optimizing the performance of production systems and processes because it is able to identify, measure, analyze, and provide solutions for continuous improvement. Basically lean aims to eliminate or reduce waste [2].

Waste can affect the company's sustainability, especially in the economic field of the production system. A production system that is not lean will cause high unit costs and low profits for the company, making it difficult to achieve sustainability in the economic sector. Therefore, the concept of downsizing or lean is considered capable of overcoming this. With lean production, sustainability from an economic standpoint will be easily achieved in the form of unit cost efficiency with maximum profit achievement. Based on sustainable development, there are three pillars that are the focus in achieving sustainability, namely social, environmental and economic [3,4]. To achieve sustainability in the economic field, good productivity must be applied to the production system [5].

Manufacturing companies looking to increase profits can make continuous improvements in productivity and quality by reducing additional working time, labor, production time, and production costs by streamlining production processes. Some of the tools that can be used to achieve sustainability in the economic field are by implementing the Kanban, Kaizen, and 5S systems [6]. The Toyota Production System (TPS) has long implemented a lean or lean production system by implementing several concepts in its production system by making continuous

improvements by finding methods that are able to minimize unit costs and increase profits from the production system side. Some of the methods applied are the Heijunka method, which is leveling production both in terms of volume and product mix [7], the Jidoka method in which there is an automation process that turns manual processes into automatic ones, and the Kanban method, which is a production order card that functions to control inventory [8].

Several studies have been conducted to maximize profit by referring to the lean concept for achieving sustainability in the economic field. [2] the concept of lean manufacturing is to maximize profit by reducing waste on the production floor and making improvements to any identified waste. [1] using the concept of lean manufacturing to increase production capacity that can maximize business profits, to identify waste that occurs use value stream mapping. [9] researching related to case studies in the automotive sector regarding the production of spare parts, the application of a combination of customized lean and green strategies resulted in a reduction of around 10.8% of the production costs of representative spare parts so that from reducing production costs, profit can be maximized. [10] in research conducted applying lean manufacturing to the furniture industry in Malaysia and the results show that deficiencies were found in lean implementation due to the challenges faced, namely in the form of technical knowledge, training, and financial resources during the initial phase of lean implementation. [11]conducted a study by applying lean manufacturing in a company to encourage an increase in the company's financial strength by making continuous improvements to the production system. [12] developing a methodology that can be applied by small and medium enterprises (SMEs), especially SMEs in the manufacturing sector, the results of research provide suggestions for the right lean tools for SMEs in maximizing profits. [13]presents a customized approach to low cost economic and ecological optimization of manufacturing processes, by identifying the relationship between ecological characteristics and Lean principles to develop an Eco Lean mindset.

Based on several previous studies, this research will develop a production system based on lean principles by adopting the method applied by the TPS, which has been proven capable of minimizing unit costs and maximizing profits by reducing waste on the production floor to achieve sustainable manufacturing in the economic field. Production system improvements can be seen through production system simulations that are run with several types of simulations that apply the TPS method, namely the heijunka, jidouka, and Kanban systems. In the production system simulation, miniature cars are used.

The purpose of this study is to obtain a production system that can minimize unit costs and maximize profits by adopting lean principles in it and referring to the method used in the Toyota Production System. The results of this study can overcome the problem of waste in production systems, especially in manufacturing. Thus the company is able to achieve its respective sustainability in the economic field, especially in the manufacturing sector by applying the best production system simulation results in minimizing unit costs and maximizing company profits after testing the production system simulation to several methods applied to TPS.

2 Literature review

2.1 Lean manufacturing

Taiichi Ohno created the TPS, which is the basis of various lean production movements. The definition of lean manufacturing is that lean is a systematic approach to identify and eliminate waste through continuous and sustainable improvement and development [11,12].

Lean is a systematic approach that can identify and reduce the occurrence of waste based on value-added activities and non-value-added activities, basically in lean continuous improvement is carried out to gain excellence in the production system by flowing products (materials, work in process, output) and information with a pull system [14,15]. Lean is being able to produce products in high quantities, have lower overhead costs, and use production resources more efficiently [16]. A company that has seen that a lean production system will provide a good change to its business, will be compelled to try implementing this system in its company [14].

According to [17] to become lean manufacturing requires a way of thinking that focuses on making the product flow through stages that provide value without any obstacles (one piece flow), a pull system originating from customer demands to achieve short processing intervals and a culture of continuous improvement diligently.

2.2 Sustainable manufacturing

The application of sustainable manufacturing in any industry, including industry in Indonesia, requires not only planning a production system based on the three pillars of sustainability (economic, social and environmental), but also a holistic implementation method to support the application of the concept of continuous improvement. Measurement of sustainability performance is always based on the triple bottom line, which focuses on environment, economy and social (Figure 1). A company will be said to have a sustainable manufacturing system if the company has been able to achieve a level of sustainability in these three aspects. However, companies cannot separate sustainability improvements in each aspect because these aspects will continue to be related. In encouraging sustainability in the economic and environmental fields, companies need to implement lean manufacturing systems. To foster sustainability in the economic and social domains, companies should adopt both large-scale manufacturing and an efficient logistics system. From a production standpoint, logistics plays a crucial role in acquiring materials from suppliers for the

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company's production processes. Simultaneously, from a marketing perspective, logistics is instrumental in the distribution of goods from the company to consumers. To increase sustainability in the environmental and social fields, companies need to implement green manufacturing. Therefore, it can be concluded that in achieving a sustainable manufacturing system, companies must implement a lean, mass and green manufacturing system To increase sustainability in the environmental and social fields, companies need to implement green manufacturing. Therefore, it can be concluded that in achieving a sustainable manufacturing system, companies must implement a lean, mass and green manufacturing system [19].

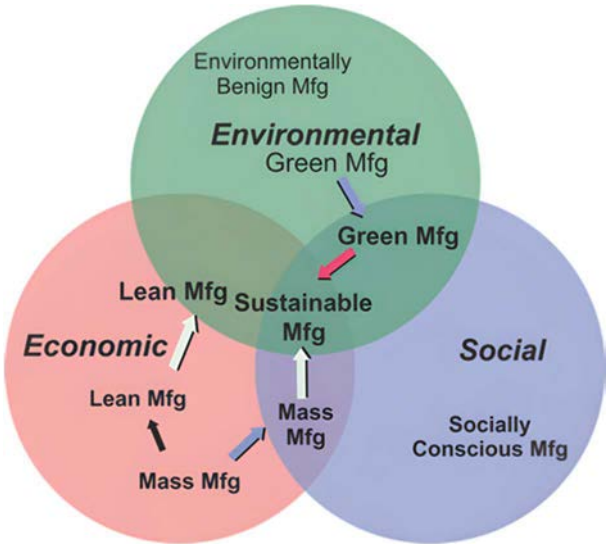

Figure 1 Sustainable manufacturing sources [18]

2.3 Toyota Production System

The application of the Toyota Production System (TPS) principle aims to expedite all production areas with various processes, achieve high quality output, reduce waste generated, achieve high quality output, and achieve low production costs in producing products. Economic benefits will be achieved by optimal inflows and outflows as well as a minimum area. The financial benefits will be enormous by applying this TPS principle in the production line. With a balance between stations in the production process, it will reduce stock in each process. This will lead to lower production costs. With effective stock management will be able to prevent the instability of a production process. In addition to balancing the process between stations, it will have implications for increasing overall production output. The process of balancing output between work stations is what will be the focus of this research [20].

According to Taiichi Ohno [21] the most basic waste is overproduction, because it accounts for most of the other waste. The TPS aims to achieve stable and lean production by expecting average production to be in balance with long-term demand forecasts which can also include variations in short-term demand. At Heijunka, reserve product inventories are carried out to deal with sudden peaks in demand so that customer orders are still fulfilled without changing production. In addition, Kanban is a scheduling approach that matches supplies with actual needs. Kanban is supported by a nameplate in the form of a card containing information on the parts that need to be provided in the production unit/facility or by outside suppliers. Visual cues such as kanbans can also be used to control overproduction and uneven production rates. Jidoka aims to design equipment in a production system capable of automatically detecting production problems and stopping when these problems occur. Examples of problems are equipment malfunctions, quality issues, or delays in worker response. The visual system is able to provide information to workers who operate machines [22]. In applying the lean concept to TPS to reduce costs, most of the production processes include the principles of Kaizen activities, flow analysis and Kanban systems [16].

3 Methodology

3.1 Data collection

Production system research based on TPS was carried out in two stages of data collection :

1. The research was carried out with experimental activities in the Manufacturing System Lab with step 1-6 simulations on the TPS for miniature car products of the Pick Up <P/U>, Double Cabin <D-Cab>, and Multi Purpose Vehicle <MPV> types.
2. Literature research, namely literature studies related to the issues, will be discussed in this study such as lean manufacturing, sustainable manufacturing, and the TPS.

3.2 Processing and analysis of data

Processing the data is done by calculating the unit cost and profit generated in each simulation that is carried out starting from step 1 to step 6. The cost components that are calculated to determine the unit cost and profit are depreciation costs, labor costs, and production costs at each product unit workstation. In this study, a comparative analysis of the unit cost and profit generated in each simulation based on the TPS was carried out.

3.3 Distribution of work stations

1. Work Station <WS> #1
   Perform the assembly of the lower part of the car by combining the chassis, front & rear axle and axle holder
2. Work Station <WS> #2
   Assembling the bottom of the car by combining the results of WS #1 and wheel products
3. Work Station <WS> #3

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Performing the assembly of the top of the car by combining the results of the WS #2 product and the body according to the model being worked on

4. Work Station <WS> #4
   Conduct quality checks and record defects found from WS #3 products

3.4 TPS simulation steps and conditions

The TPS simulation (Figure 2) is carried out with 2 cycle times with a takt time of 90 minutes. Cycle Time (CT) is how long it takes to produce an output, including non-value added activities and value added or the time it takes an operator to complete 1 cycle of work including to do manual work and walk. Takt time is not a tool, it is a concept used to design a job and measure the tempo of customer demands. Takt Time (TT) is the time available to produce an item or service divided by the amount of products or services demanded by the customer in that period [23]. Each cycle time is fulfilling 5 demands out of 10 total demands.

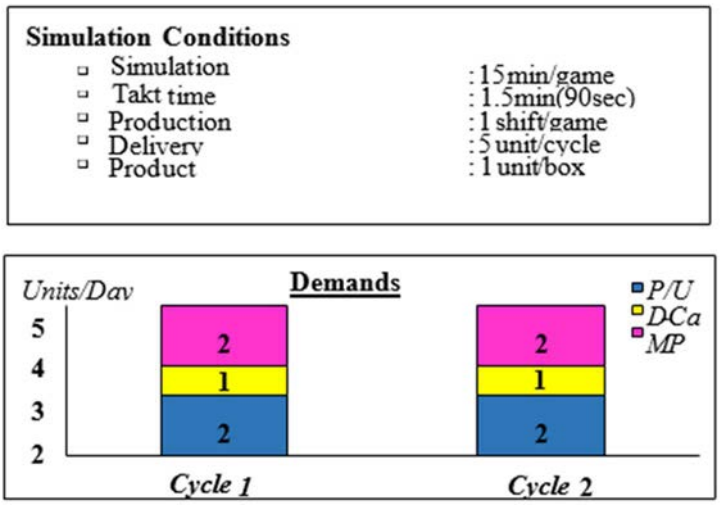

Figure 2 Simulation conditions

Simulation #1 (Figure 3):

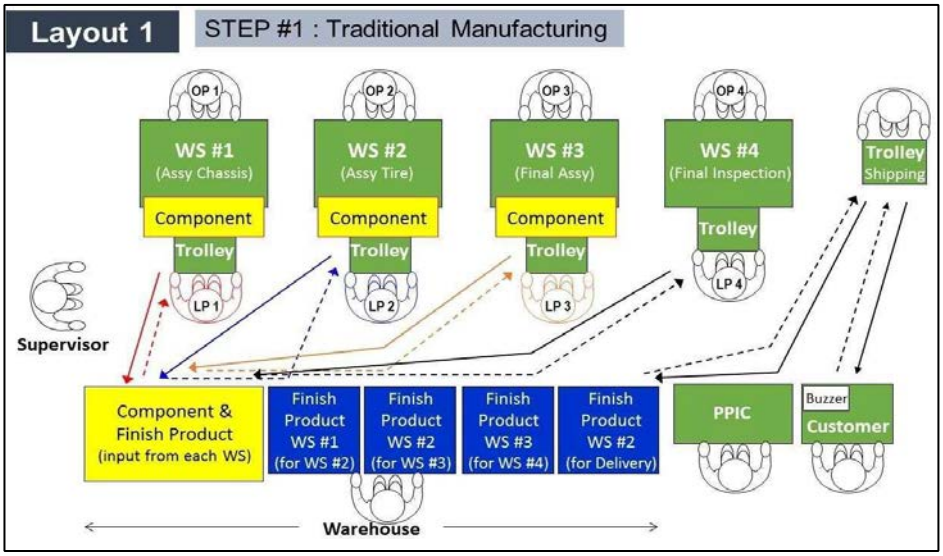

Figure 3 Traditional manufacturing
Source [24]

In simulation #1 the company implements a production system that is still traditional where it uses a warehouse as a centralized place for both material stocks as well as finished goods stocks and semi-stock stocks and those ready to be sent to customers.

Simulation #2 (Figure 4):

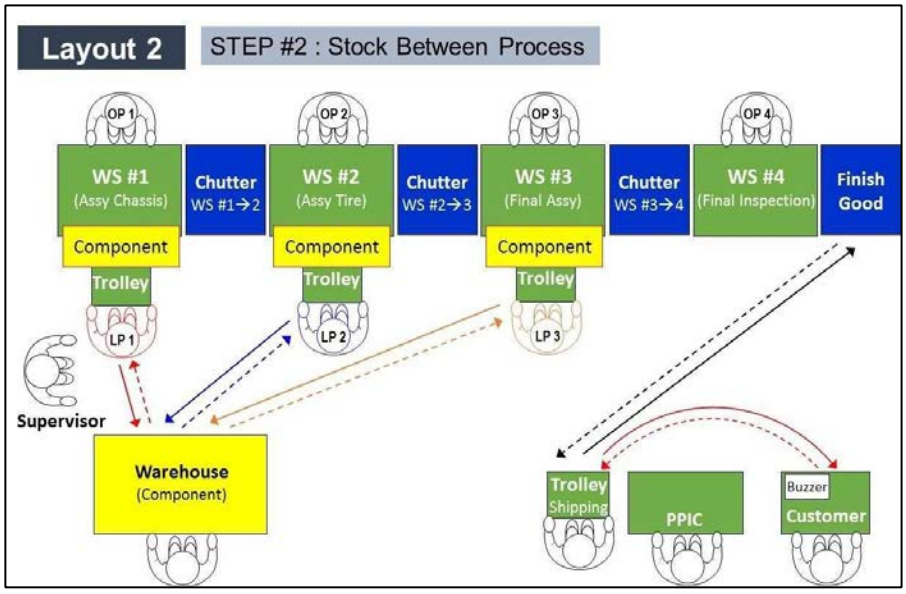

Figure 4 Stock Between Processes
Source [24]

In simulation # 2 the company implements a production systemwho have implemented a store at each work station and warehouse only as a place to store materials and still use production orders in the form of a schedule.

Simulations #3 and #4 (Figure 5):

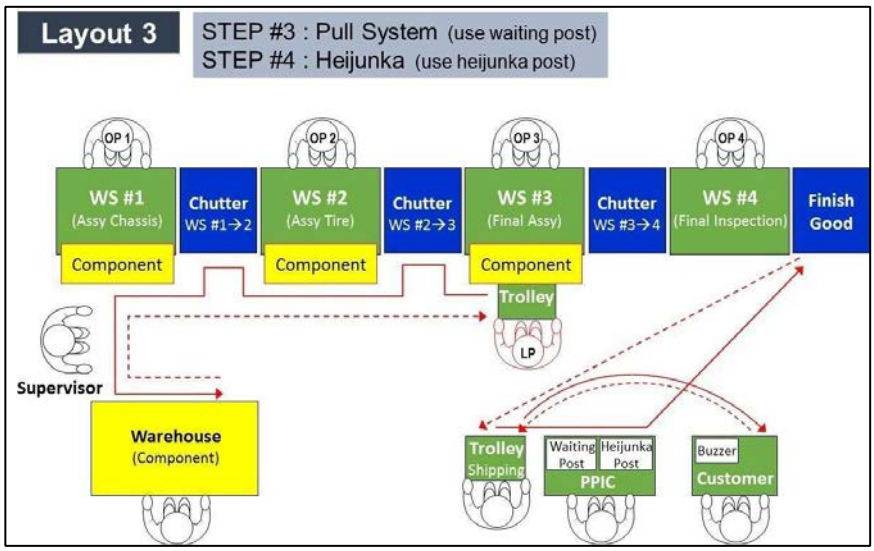

Figure 5 Pull System and Heijunka
Source [24]

In simulation # 3 the production system implemented by the company is a pull system at each work station, in this simulation Kanban and waiting post are used, the Kanban function is a card for production orders while the waiting post function is a tool to obtain information from visualized customer.

In simulation #4 the production system applied is a pull system and heijunka post which are tools with the aim of equalizing the operator's workload.

Simulation #5 (Figure 6):

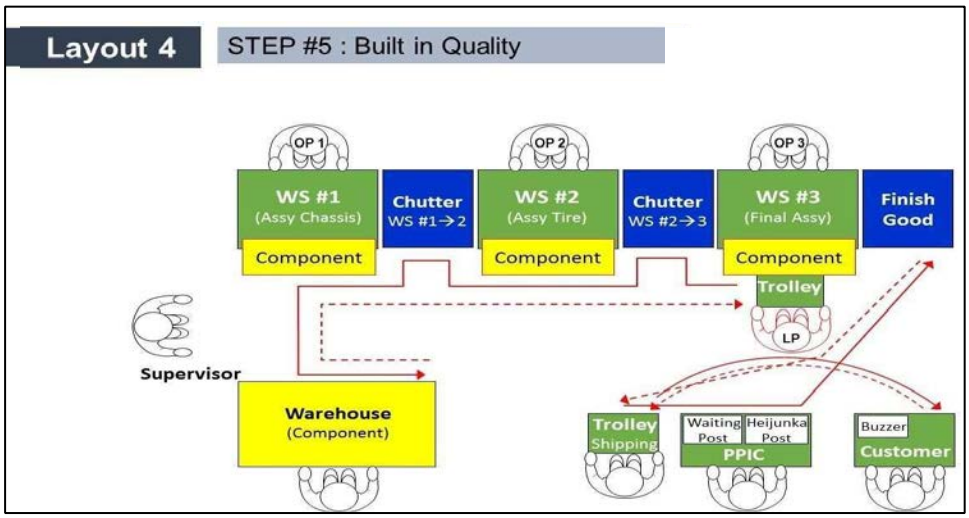

Figure 6 Built-in Quality
Source [24]

In simulation # 5 the company implements a production system with Built-in Quality (does not receive, manufacture and forward NG goods) in simulation 5 each work station operator must check product quality and ensure the point quality of his work.

Simulation #6 (Figure 7):

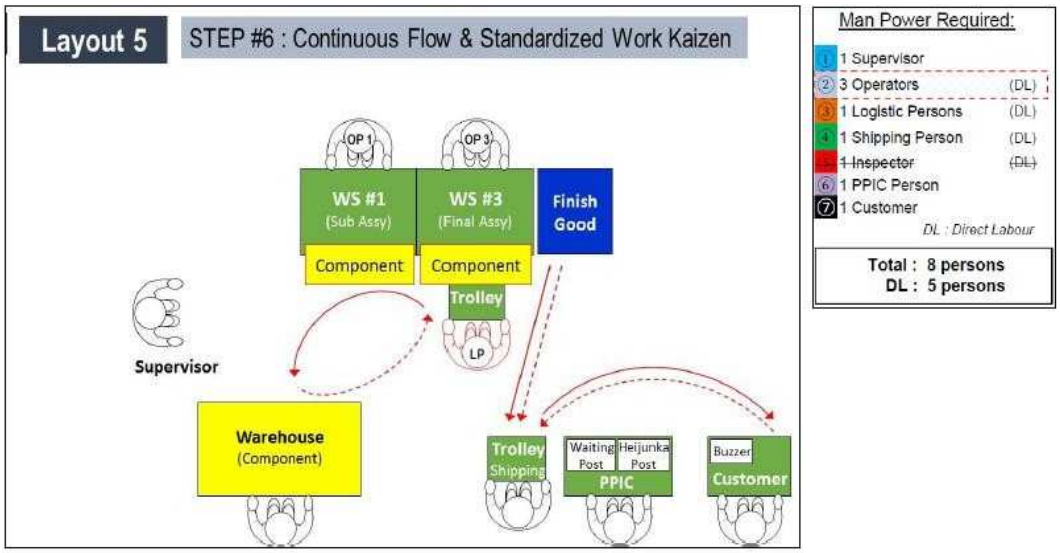

Figure 7 Continuous Flow & Standardized Work Kaizen
Source [24]

In simulation # 6 the company implements a production system which implements TPS by flowing each one part and reviewing work standardization based on Takt Time [24].

4 Results and discussions

To process the data, the reserachers calculate the total cost at each workstation for each simulation. The total cost is calculated to find out the unit cost, profit, and no good rate in each simulation. Profit and unit costs generated in each simulation will be analyzed to get the best simulation. Each simulation uses a different method. Simulation 1 uses traditional manufacturing, simulation 2 uses stock between process, simulation 3 uses a pull system, simulation 4 uses heijunka, simulation 5 uses build-in quality, and simulation 6 uses continuous flow and standardized work kaizen. The following calculation is a description for simulation 1

(traditional manufacturing), which consists of calculating the total cost based on the cost of good production and no good production at each workstation. The number of orders for each simulation is the same, namely 10 units of cars consisting of Pick Up <P/U>, Double Cabin <D-Cab>, and Multi Purpose Vehicle <MPV> types in each simulation.

Simulation #1

1. *Total Cost*WAS #1
   cost = $10
   goodproduction = *Quantity*x Cost = 1 x $10 = $10
   No good production = *Quantity*x Cost = 0 x $10 = 0
   total cost = *good Product*+ No good Product = $10 + 0 = $10
2. *Total Cost*WAS #2
   cost = $20
   goodproduction = *Quantity* x Cost = 4 x $20 = $80
   No good production = *Quantity* x Cost = 0 x $20 = 0
   total cost = *good Product* + No good Product = $80 + 0 = $80
3. *Total Cost*WAS #3
   cost = $30
   goodproduction = *Quantity* x Cost = 3 x $30 = $90
   No good production = *Quantity* x Cost = 0 x $30 = 0
   total cost = *good Product* + No good Product = $90 + 0 = $90
4. *Total Cost*WS #1 #2 #3
   total cost = WS#1 + WS#2 + WS#3 = $10 + $80 + $90 = $180
   So, the total cost obtained in WS #1 #2 #3 Simulation 1 is $ 180.
5. *Total Cost*WAS #4
   cost = $40
   goodproduction = *Quantity* x Cost = 4 x $40 = $160
   No good production = *Quantity* x Cost = 6 x $40 = $240
   total cost = *good Product* + No good Product = $160 + $240 = $400
6. *Shipping*
   Number Of Orders = 10 Pcs
   Cost Delivery (On Time) = $100 x Quantity = $100 x 7 = $700
   Cost Delivery (Delayed) = $80 x Quantity = $80 x 0 = $0
   Total Delivery(d) = 9
   Cost Undelivered /Reject Product = **$**30 x Quantity = $30 x 3 = $90
   Total Income = *Cost Delivery - Cost Undelivered* = $700 - $90 = $610

   So, the total income earned on shipping Simulation 1 is $610.

   Unit cost = (Fixed Cost + Total Cost WS #1#2 #3 + Total Cost WS #4) / Total Delivery
   = ($200 + $180 + $400) / 7 = $111
   Profit = *Total Income*– (Fixed Cost + Total Cost WS #1 #2 #3 + Total Cost WS #4 + Labor Cost)
   = $610 – ($200 + $180+ $400+ $180) = -$350

   Quality(NG Rate) $= \frac{Total\ \text{NG WS\#4}}{Total\ Order\ Customer}\ x\ 100\% = \frac{6}{10}\ x\ 100\% = 60\%$

   To calculate the unit cost and profit in each simulation, Ms. Excel, the following are the calculation results in simulation 1 shown in Table 1.

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Table 1 Lean Manufacturing Simulation 1 Evaluation Sheet

Lean Manufacturing Simulation Evaluation Sheet Round #1 — fill in the blue column

The cost of depreciation is fixed:							$	200	----> A
Labour			No. of Labour:	12			$	15	----> F
Cost of Labour							$	180	
WS	Area	Status	Quantity (Q)			Cost ©	Total Cost (Q x C)		
#1	In Process product	Good Product		Pcs		$ 10	$	-	
		No Good Product		Pcs		$ 10	$	-	
	In Warehouse	Good Product	1	Pcs		$ 10	$	10	
			Sub Total 1				$	10	----> 1
#2	In Process product	Good Product		Pcs		$ 20	$	-	
		No Good Product		Pcs		$ 20	$	-	
	In Warehouse	Good Product	4	Pcs		$ 20	$	80	
			Sub Total 2				$	80	----> 2
#3	In Process product	Good Product		Pcs		$ 30	$	-	
		No Good Product		Pcs		$ 30	$	-	
	In Warehouse	Good Product	3	Pcs		$ 30	$	90	
			Sub Total 3				$	90	----> 3
			Total 1 + 2 + 3				$	180	----> B
#4	Final Inspection	Good Product	4	Pcs		$ 40	$	160	
		No Good Product	6	Pcs		$ 40	$	240	
			Total				$	400	----> C
SHIPPING	Number of Order		10	Pcs					
	Delivery	On time	7	Pcs		$ 100	$	700	
		Delayed		Pcs		$ 80	$	-	
		Total Delivery (D)	7,00	Pcs					
	Undelivered /Reject Product		3	Pcs		$ -30	$	(90)	
						Total Income	$	610	----> E
	Unit Cost	(A + B + C) / D					$	111	----> G
	Profit	E - (A + B + C + F)					$	(350)	
	Customer Satisfaction	On time delivery	7	Pcs					----> H
		Late delivery	0	Pcs					----> I
		Undelivered	3	Pcs					----> J
		Total delivery = ((H/(I+J))x 100%)						70%	
	Quality	NG rate	60%	%		(NG A + NG B + NG C + NG FI) / (Production total in all processes)			

The results of the comparison of company profits from each simulation can be seen in the table below (Table 2).

Table 2 Comparison of simulation results

Simulation	*WS #1*	*WS #2*	*WS #3*	*WS #4*	*Total income*	*Unit cost*	*Profit*	*Quality (No Good Rate)*	*Man Power*
1	$10	$80	$90	$400	$610	$111	-$350	60%	12
2	$10	$80	$180	$400	$870	$97	-$165	10%	11
3	$10	$20	$150	$440	$1000	$82	$45	20%	9
4	$10	$40	$150	$240	$1000	$64	$225	0%	9
5	$10	$0	$240	-	$870	$50	$300	0%	8
6	-	$20	$120	-	$1000	$34	$540	0%	7

The TPS simulation involves several work sections consisting of four workstations, a warehouse section, a Production Planning and Inventory Control section. Each work station has its own workload which is carried out by the operator and limited by the supervisor. In simulation 1, namely traditional manufacturing involving 12 workers with 4 workstations, in simulation 2 involving 11 workers with 4 workstations, in simulations 3 and 4 involving 9

workers for 4 workstations, in simulation 5 involving 8 workers for 3 workstations, and in simulation 6 which involved 7 workers for 2 work stations. Based on the division of labor for each simulation, it can be seen that from simulations 1 to 6 there was a decrease in the number of workers, which was also followed by a reduction in the number of workstations. Except for simulations 3 and 4, they still use the same number of workers and workstations, this is because what was done was only changes to the production flow with the lean concept applied in simulation 3, namely the pull system and simulation 4, namely heijunka

Based on the results in table 1, a comparison of the simulation results can be seen. Setup simulation 1 (traditional manufacturing) consistsfrom 1 supervisor, 1 Production Planning Inventory Control (PPIC), 1 shipping person, 4 work station operators, 4 logistics persons, and 1 warehouse person. In this simulation, the company implements a traditional production system because it uses a warehouse as a place for stock centralization which consists of stock of finished goods, stock of semi-finished goods which are then sent to customers. The simulation results show that the unit cost value is $111, the profit value is - $ 350, and the quality (NG Rate) is 60%.

Setup simulation 2 (stock between process) consisting of 1 supervisor, 1 PPIC person, 1 shipping person, 4 operators, 3 logistics persons, and 1 warehouse person. In this case the logistics person for WS #4 is eliminated because in this simulation, the company implements a production system that has implemented a store at each work station and the warehouse is only a place for storing materials. From the simulation results, it is known that the unit cost value is $ 97, the profit value is - $ 165, and the quality (NG rate) is 10%.

Simulation setup 3 (pull system) consists of 1 supervisor, 1 PPIC person, 1 shipping person, 4 operators, 1 logistics person, and 1 warehouse person. In this case, the logistics person for WS 1 and 2 is omitted. So there is only 1 logistics person left to deliver materials to each work station. This is because the company's production system applies a pull system method at each work station. In this simulation, kanban and waiting post are used, the Kanban function is a card for production orders while the waiting post function is a tool to obtain information from visualized customers. The simulation results show that the unit cost value is $ 82, the profit value is $ 45, and the quality (NG rate) is 20%.

Simulation setup 4 (heijunka) consists of 1 supervisor, 1 PPIC person, 1 shipping person, 4 operators, 1 logistics person, and 1 warehouse person. In this simulation, the condition of the company implementing a production system is the pull system method at each work station and using heijunka posts as a tool to equalize the operator's workload. . From the simulation results, it is known that the unit cost value is $ 64, the profit value is $ 225, and the quality (NG rate) is 0%.

Simulation setup 5 (built-in quality) consists of 1 supervisor, 1 PPIC person, 1 shipping person, 3 operators, 1 logistics person, and 1 warehouse person. In this respect, work station 4 as the inspector is omitted. This is because the company implements a production system with built-in quality (does not receive, manufacture, and forward no good products) in a way that each work station ensures the quality of their respective work. Therefore, it is known that the unit cost value is $ 50, while the profit value is $ 300, and the quality (NG Rate) is 0%.

Simulation 6 setup consists of 1 supervisor, 1 PPIC person, 1 shipping person, 2 operators, 1 logistics person, and 1 warehouse person. In this case, the work station 2 operator is omitted because in this simulation, the company applies a process layout using 2 work stations and divides the work. As a result, it is known that the unit cost value is $ 34, the profit value is $ 540, and the quality (NG rate) is 0%.

In determining profit, a "profit planning approach" analysis is carried out which is based on the relationship between costs (cost) and income (income), the amount of income can be known based on the amount of demand [25]. In the simulations performed, it is known that the production costs calculated to determine profit are depreciation costs, labor costs, and production costs based on each workstation per unit product. The cost of producing a product per unit is divided into two types, namely the cost of good product and no good product. Good product means that the product produced is fit for sale in the market and meets quality control standards, while no good product means a product that does not meet quality standards and is not fit for sale in the market. In the production system simulation based on the TPS concept, the number of demands is assumed to be 10 units for three types of cars. The selling price to determine the amount of income is divided into three, namely the selling price of the product that is on time, the selling price of the product that is delayed, and the selling price of undelivered/rejected products. Total income is obtained based on three types of product selling prices. While the amount of profit is obtained based on the difference between the amount of income and depreciation costs, production costs incurred at each workstation for each simulation and labor costs. The total cost of production becomes one of the variables to calculate the unit cost. The unit cost is obtained by calculating the depreciation cost and the total production cost at each workstation then divided by the total product successfully delivered to the customer. production costs incurred on each workstation for each simulation and labor costs. The total cost of production becomes one of the variables to calculate the unit cost. It is obtained by calculating the depreciation cost and the total production cost at each workstation then divided by the total product successfully delivered to the customer. production costs incurred on each workstation for each simulation and labor costs. The total cost of production becomes one of the variables to calculate the unit cost. It is obtained by

calculating the depreciation cost and the total production cost at each workstation then divided by the total product successfully delivered to the customer.

Customer satisfaction is the main goal for business actors. Customer (consumer) satisfaction is the ability of a product to meet or exceed consumer expectations and desires [26]. Customer satisfaction determines the success and failure of the company. Therefore, it is very important to know and understand whether the customer is satisfied with the services provided by the company. Calculation of customer satisfaction is based on the TPS concept by considering the number of products that are on time delivery, late delivery, and undelivered.

To see how much the level of product quality is produced, the TPS concept also calculates the Quality rate. The quality rate is determined based on the number of products that fall into no good product category at each workstation. The purpose of calculating the quality rate is to determine the level of production effectiveness in the production system that is run based on the quality of the resulting product [27].

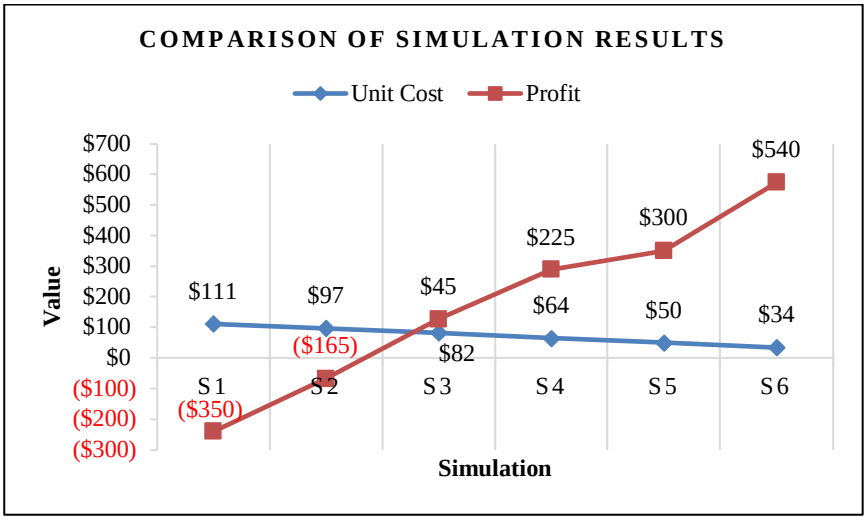

Figure 8 Comparison of simulation results

Based on the simulation results 1 to 6, the unit cost and profit values are different. Based on figure 8, it shows that the value for the unit cost starting from simulation 1 to 6 is getting smaller. This also happens to the profit value which shows that from simulations 1 to 6 it is increasing. With reference to the unit cost and profit values generated in the graphic images, it can be concluded that using the same number of orders with different work methods, it will affect how much the unit cost and profit values are obtained by the company. Simulation 1 which still uses the traditional method produces the largest unit cost and the lowest profit, however, in simulation 5, the workstation was streamlined, namely the quality control section. The role of quality control is held by each operator at workstations 1 to 3. Likewise with simulation 6 which applies the lean concept by applying kaizen in the process. From the unit cost results for simulations 5 and 6 there was a decrease and an increase in profit.

Referring to the work method for the car production system by running simulations 1 and 6, lower unit costs and higher profits are produced by adopting the lean concept in the production system. This can support the achievement of sustainability in the economic field by obtaining work methods that are able to produce low unit costs and maximum profits.

5 Conclusions

Based on the research results by running 6 simulations based on TPS obtained unit cost and profit results for each simulation. Simulation 1 shows the highest unit cost, which is $111 when compared to simulations 2 to 6 which have implemented lean principles in their production systems. Likewise, with the profit generated, simulation 1 produces the lowest profit, which is -$359 when compared to simulations 2 to 6. The profit generated by simulation 1 shows that the production system that is run in simulation 1 results in losses for the company with a minus profit value. From simulations 1 to 6, the unit cost results are getting lower, as well as the profit earned is increasing. Simulations using lean concept implemented by TPS show that the continuous improvement steps being carried out are increasing in simulations 2 to 6 by applying the lean concept. The results obtained show that the greater the lean steps taken by the company, the smaller the unit cost will be and the higher the profit will be. In addition to calculating unit cost and profits, each simulation also calculates the percentage of customer satisfaction and quality rate. If implementing the lean concept in the production system, the company has the potential to achieve maximum profits because the unit cost is also low. However, a potential drawback when implementing the lean concept is the increased workload for manpower, as

the concept also involves reducing manpower. Therefore, it is necessary to measure the workload for manpower before deciding to implement the lean concept, which includes manpower reduction.

If the lean concept is applied to the production system, the company's sustainability, especially in the economic field, can be achieved by obtaining a small unit cost and maximum profit. The results of this study can be a suggestion for business actors, especially in the manufacturing sector, to apply the lean concept with reference to continuous improvement. Sustainable improvement steps with the lean concept can be undertaken by applying several concepts used in the TPS to its production system, such as Heijunka System, Jidouka, and Kanban. Furthermore, the lean concept can also be implemented in the production system by making technological improvements and leveraging digitization, which can streamline the production system.

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Streamlining logistics flows with lean tools using TX Plant Simulation software support
Miriam Pekarcikova, Peter Trebuna, Michal Dic, Jaroslav Markovic

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Streamlining logistics flows with lean tools using TX Plant Simulation software support

Miriam Pekarcikova
Technical university of Košice, Faculty of Mechanical Engineering, Department of Industrial and Digital engineering, Park Komenského 9, 042 00 Košice, Slovak Republic, EU, miriam.pekarcikova@tuke.sk (corresponding author)
Peter Trebuna
Technical university of Košice, Faculty of Mechanical Engineering, Department of Industrial and Digital engineering, Park Komenského 9, 042 00 Košice, Slovak Republic, EU, peter.trebuna@tuke.sk
Michal Dic
Technical university of Košice, Faculty of Mechanical Engineering, Department of Industrial and Digital engineering, Park Komenského 9, 042 00 Košice, Slovak Republic, EU, michal.dic@student.tuke.sk
Jaroslav Markovic
University of Zilina, Faculty of Mechanical Engineering, Department of Industrial Engineering, Univerzitna 8215/1, 010 26 Zilina, Slovak Republic, EU, jaroslav.markovic@fstroj.uniza.sk

Keywords: logistics, lean, model, simulation, efficiency.
Abstract: A critical factor in the manufacturing industry is waste and losses in individual operations and processes. The expansion of elements of lean production, such as the pull system with the interconnection of key technologies, brings new elements of production planning and control. Thanks to new technologies, many more possibilities exist to uncover potential bottlenecks. Simulations and modelling bring new possibilities for experimentation in the virtual environment of prepared systems or devices without directly disturbing the functioning system. The presented article deals with the issue of applying lean approaches in finding optimal solutions within logistics flows. The aim of the article is to define and test the potential for streamlining logistics flows with TX Plant Simulation software support. The research and empirical part of the study was solved based on a rigorous analysis of the initial situation in a specific company for the selected product group, as the Value Stream Mapping method was used for the analysis. A simulation model of a real line was created in the TX Plant Simulation software with the help of the Value Stream Mapping library for value creation, which is part of the software. The goal was to find out possible waste within the logistics flow, and its causes and propose the necessary steps to eliminate the waste.

1 Introduction

The current trends in the manufacturing industry include the acceleration of product development, the earliest possible start of production, the growth of flexibility, quality, and variability of production in conjunction with low costs. Changing demands from customers, changing products, and developing technologies all affect the structure of business processes, and affect work procedures, input materials, and production equipment. From this also follows the need to achieve adaptability of enterprise processors, which, however, must pass through all hierarchical levels. It is possible to reflect on this challenge through the evolutionary concept of Industry 4.0. The basic pillars of Industry 4.0 are digitization (of products, processes, equipment, and services) and the application of exponential technologies. However, the transformation of the enterprise into a smart factory will require expertise and know-how in all functional areas of the enterprise. This concept is already known from ten years ago when it was presented at the Hannover Mess. However, it is a question of how it penetrated industrial reality [1-3].

From the point of view of designing and developing production and logistics systems, it is necessary to look at the difference between flexible and adaptable systems. Flexibility means the ability to respond to changes within a predetermined range of requirements efficiently, timewise, and cost-effectively. In terms of manufacturing logistics, flexibility involves adapting structures and processes to changes at the tactical level by referring to the joint interaction of employees, machines, production systems, and the network to create value. Adaptability exceeds flexibility because it represents the system's potential to respond to changes beyond predetermined corridors of activity and to proactively respond to changes. In logistics, adaptability means the ability of a material flow system to adapt to new circumstances by being variable. Processes and systems can be changed and modified. Achieving these goals is conditional on the implementation of new technologies capable of handling such demands. Product functionality verification in a virtual environment will be an essential standard soon. With increasing global competition and increasing customer demands, the importance of improving business processes is growing. In recent years, the term lean management has become more and more frequently

associated with this connection. The origin of this approach to management is associated with the Japanese company Toyota, and thanks to the ability to respond more quickly and flexibly to customer requirements, it has penetrated the entire world, and gradually increasing case studies testify to ever-new areas of its use [4-10].

The concept of lean thinking describes the work philosophy and practices of the Toyota Production System. In TPS, the use of a resource that does not add any value according to the customer is excluded [5]. The processes work on the principles of using less material, requiring less investment, using less inventory, needing less space, and using fewer people [11-13].

Achieving a value stream in lean manufacturing consists of four key strategies [11]:

- Synchronization of external deliveries to customers.
- Internal production synchronization.
- Flow formation.
- Creation of a traction system.

The main goal of these strategies is the elimination of losses [11]:

- Transportation.
- Waiting.
- Overproduction.
- Defects and repairs.
- Storage.
- Movement.
- Redundant processing

When trying to improve processes, many companies encounter the problem that there is no person who has the necessary knowledge about the entire flow of material and information, or about all the processes associated with the product. A common method that enables this deficit to be overcome and at the same time to identify areas where improvement efforts should be directed and solutions suitable for the entire company should be proposed is value flow mapping. The interface between process innovation and process improvement is not well defined. Innovations constitute a more radical leapfrog transformation in the process. Under the word improvement, we imagine the activities of people involved in processes who try to increase their performance daily (elimination of waste, expenses, downtime, increasing performance and quality). Improving the overall process chain as a complete system of activities involves value stream mapping which is also the focus of the case study below [14-16].

2 Methodology

2.1 Input data for creating a simulation model

The company under investigation looks at each request for a new bar line individually, uses experience from several realized projects, listens to customers and considers their ideas about the product, and uses its test center either to develop and design new ideas or to verify customer recipes on a test bar line.

The bar line is a technological device suitable mainly to produce bars, prepared from several materials and various ingredients, such as classic cereal, nut, oat, coconut, marzipan or caramel, popular protein beetroot and fruit raw, or other mixed recipes. I can also mention various specialties such as French nougat, dried bananas, and apricots in chocolate or multi-layer bars. In Tab. 1 we can see processes related to the production of the bar.

Table 1 Processes related to the production of the bar

Description of the bar manufacturing process	
Area	**Information**
Customer	• the required number of sticks is 100,000 pieces in 2 weeks • one type of bar - nut, caramel, or fruit covered in chocolate • the average number of working days in a month is 20 (net shift time fund is 480 min.) • packaging of finished bars - 50 pieces in a box
Supplier	• supplies the necessary raw materials (nuts, caramel, fruit mixture, chocolate, packaging) • raw materials are stored in the warehouse
Planning	• all communication with the customer and supplier is electronic • planning accepts weekly or daily refinements • information on the daily production plan is based on the physical inventory of the warehouse)
Expedition	• it will be shipped from the warehouse in 2 weeks
Production	• input caramel, nuts and chocolate • melting caramel, grinding nuts and chocolate • mixing caramel and nuts and mixing with fruit mixture • solidification of the mixture and melting of the chocolate • cutting the mixture into bars of the appropriate size • coating the bar with chocolate and its solidification and control • printing and cutting the package and wrapping the bar • storage in boxes and waiting in the warehouse for dispatch

2.2 Simulation model of the production of the selected product

In the TX Plant Simulation VSM library, we simulated the production of a chocolate bar filled with nuts, caramel, and a fruit mixture. The customer requests to produce

100,000 pieces of this type of bar within 2 weeks. Chocolate, nuts, and caramel enter the simulation from separate inputs. The chocolate is ground and then melted. The nuts are also ground and mixed with the melted caramel into one mixture. After that, a fruit mixture is mixed with the mixture of nuts and caramel, which comes from another separate entrance and is subsequently cooled to a solid state cut into smaller pieces, and travels to the intermediate warehouse. From it, the solidified cut mixture is coated with chocolate and the process of chocolate solidification follows. After solidification, the worker checks the formed sticks, and they go further to the intermediate storage 2.

During these operations, the bar wrapper is printed from a separate input and then cut to the required size. The last station is the packaging of the bar, where one worker is also present to check possible defective pieces. The others are packed in boxes and that's the end of the process. The course of the simulation can be seen in Figure 1.

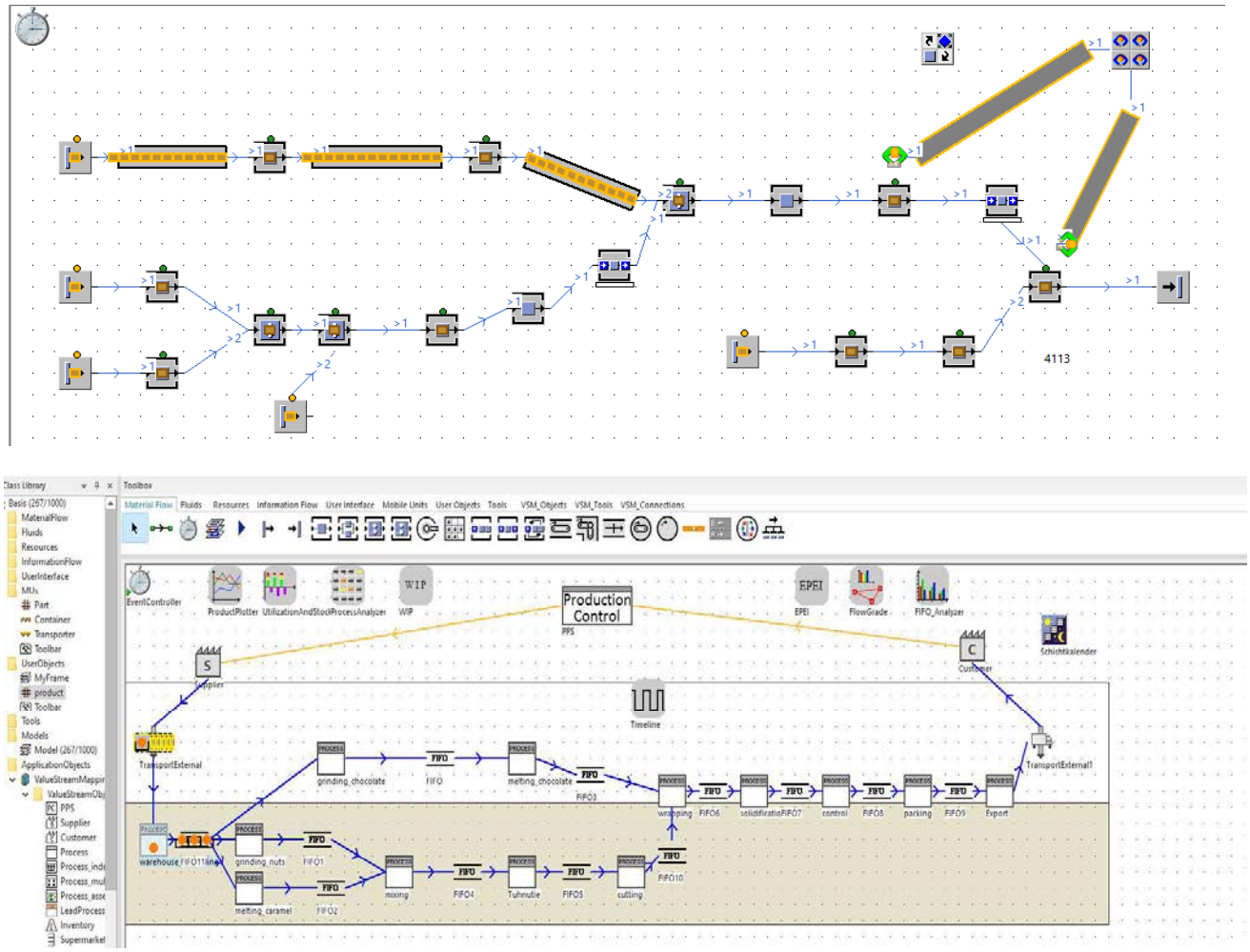

Figure 1 Simulation of the current state – process diagram and WSM diagram

After the end of the simulation, we will see the final table of produced pieces, see Table 2

Table 2 Result information after simulation – current state

.Models.Model

Simulation time:8:00:00.0000

Object	Name	Mean Life Time	Throughput	TPH	Production	Transport	Storage	Value added	Portion
output_product	Part	40.3741	4112	514	95.27%	0.00%	4.73%	59.39%	

Cumulated statistics of the parts which the drain deleted.

From this table, we find that 4,112 bars are produced in 8 hours, the productivity of the simulation is 95.27%, the storage is 4.73%, and the added value of the entire simulation is 59.39%.

Table 3 Resulting indicators of the current state

Total number of operations	14
Number of value-adding operations	8
The ratio of adding operations / total operations	**57.14%**
Time of value-adding operations (min)	3840
Time of non-value-adding operations (min)	2880
Total production time (days)	5.68
VA index	**11.16**

From the process diagram, we gradually drew a map of the value stream in the TX Plant Simulation library, see Figure 2.

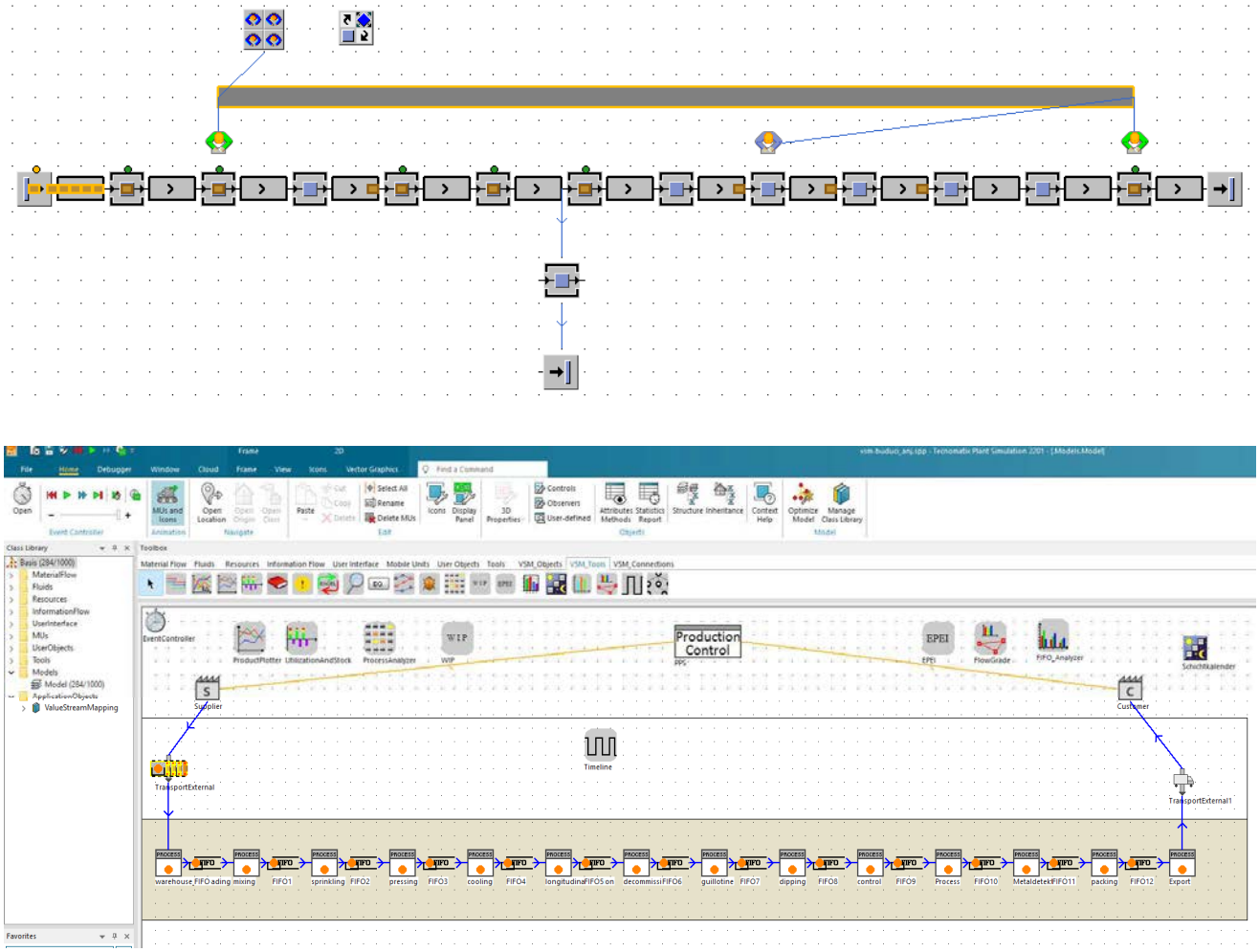

Figure 2 Simulation of the proposal state – process diagram and WSM diagram

After the end of the simulation, we will see the final table of produced pieces, see Table 4.

Table 4 Result information after simulation – proposal state

.Models.Model

Simulation time:8:00:00.0000

Object	Name	Mean Life Time	Throughput	TPH	Production	Transport	Storage	Value added	Portion
output_product	Part	1:26.0045	5692	712	55.82%	44.18%	0.00%	50.00%	
output_snippets	Part	56.7500	58	7	47.58%	52.42%	0.00%	38.77%	

Cumulated statistics of the parts which the drain deleted.

3 Result and discussion

After simulating the current situation, we found that 4,112 sticks are produced in eight hours of one shift, that is, 8,224 sticks are produced in a day with a two-shift operation. If the customer requests 100,000 pcs in two weeks, which is 10 working days, only 82,240 pcs will be produced, so we will reach the goal of 100,000 pcs in only 13 working days.

After simulating the future state, we found that in eight hours of one shift, 5,692 pcs of sticks are produced, which is 1,580 pcs more than in the current state, while another 58 pcs are scraps. During the two-shift operation, 11,384 pieces are produced per day and 116 pieces of offcuts are created. If the customer still requires 100,000 pcs in two weeks, which is 10 working days, 113,840 pcs will be produced, which means we will reach this goal. More positive is the fact that we will exceed it one day earlier, that is, in nine days.

For a better understanding of these results, we can also display them graphically in Figure 3.

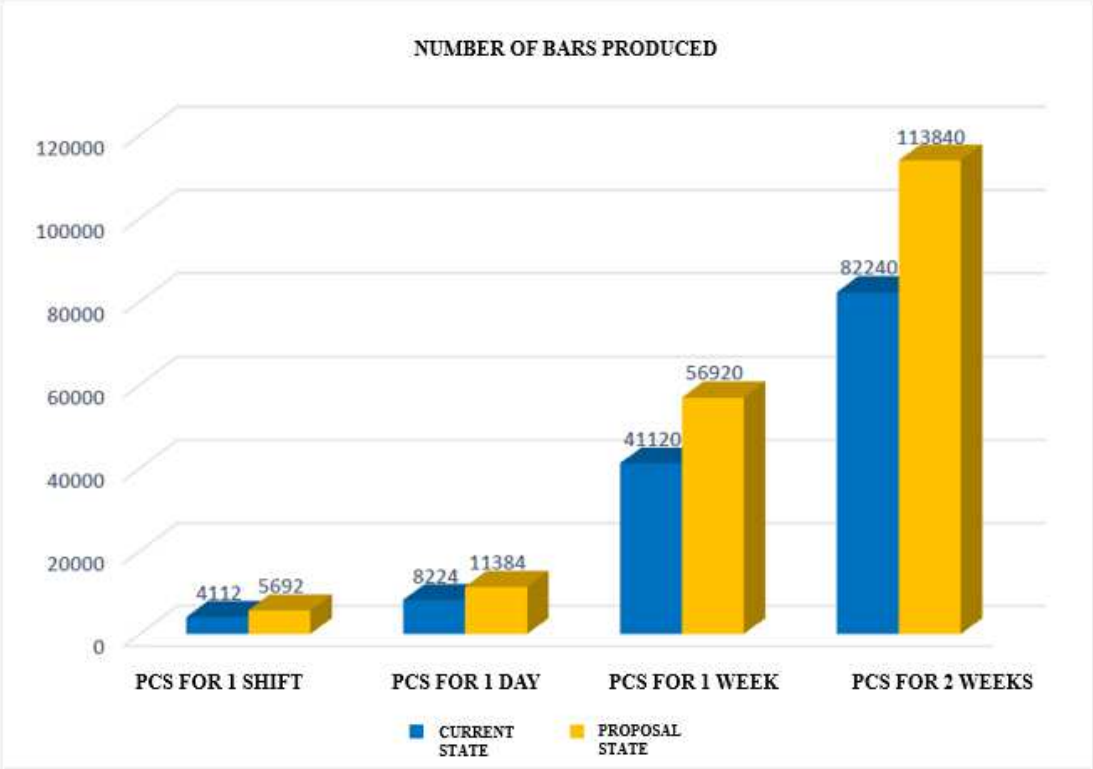

Figure 3 Graphical representation of produced pieces of bars

The added value of the entire current simulation is 59.39%. The added value of the entire future simulation is 51.68%, which is 7.71% less than the current one, but a larger number of bars will be produced and in a shorter time. The productivity of the current simulation is 95.27% and the productivity of the future simulation is 57.30%. The ratio of value-added activities to the total number of activities is 57.14% in the current state and 53.85% in the future state. The last compared indicator is the VA index, where in the current simulation it has a value of 11.16% and in the future simulation it has a value of 35%.

These indicators can also be seen in Figure 4.

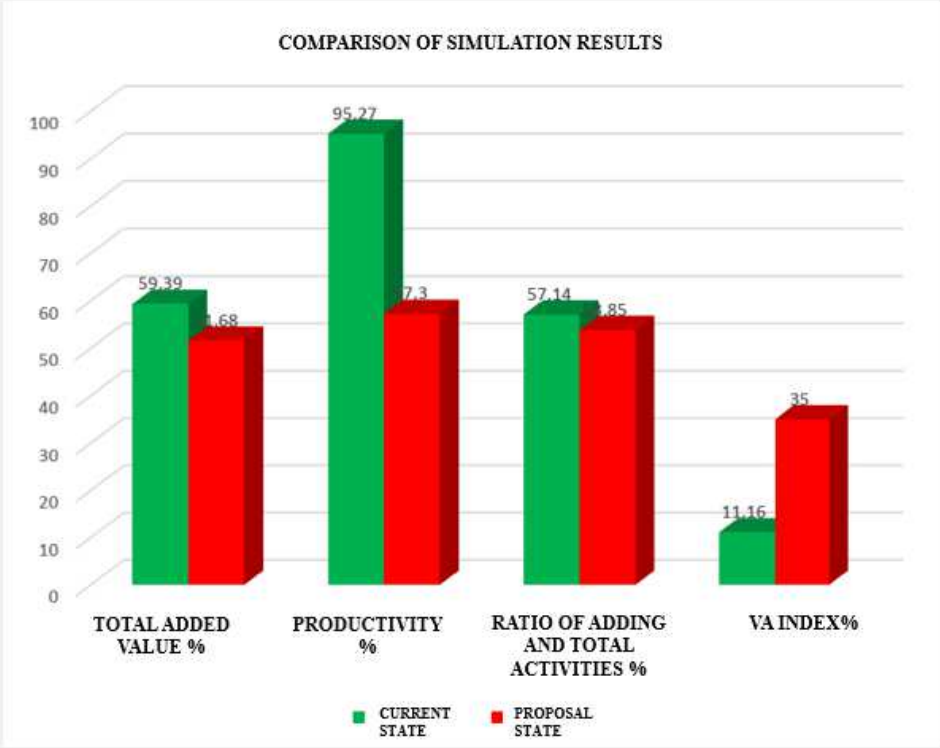

Figure 4 Graphical display of percentage comparison of simulations

Although some indicators show the current state as better, we must also look at the customer's requirements. Since it was requested to complete the order in two weeks, a future simulation where more pieces of sticks are produced in a shorter time is more acceptable. Here, too, the rule that less is sometimes more is confirmed.

Value stream mapping is one of the most important methods that a company can use to increase its productivity. By mapping, we get an overview of the activities taking place in the company, in specific places at the current time. By mapping, we can deduce how much time, space, and effort a certain activity will take, and thus we are able to eliminate waste. The map is much more complex, it contains time intervals, so it is better to create it by handwriting directly at the workplace, rather than complicated and inconvenient on the computer.

When using the VSM - Value Stream Mapping method as a tool for redesigning production flows, the key output is the VAI - Value Added Index. However, the production flow in operation is not smooth, there are frequent downtimes of material (or production in progress), due to the accumulation of stocks before technological operations - this is an activity that does not add value to the product and therefore neither to the customer nor to the production company. The company subsequently tries to minimize the times that do not add value as part of continuous improvement.

This work dealt with the mapping of the value flow in the production of bars in a specific company. It was necessary to focus on a specific type of product and production because the company is not focused on mass production, but on custom production, where different machines or devices are always produced, as well as different confectionery. Therefore, it is difficult to calculate various indexes and downtimes because each order is original. By using simulation software, the company can save costs in the event of unsuccessful prototypes or introduced changes directly into production. On the simulation model, as was pointed out in the thesis, it is possible to try the introduction of new operating systems, without directly interfering with the real company.

4 Conclusions

Value stream mapping is one of the most important methods that a company can use to increase its productivity. By mapping, we get an overview of the activities taking place in the company, in specific places at the current time. By mapping, we can deduce how much time, space and effort a certain activity will take, and thus we are able to eliminate waste. The map is much more complex, it contains time intervals, so it is better to create it by handwriting directly at the workplace, rather than complicated and inconvenient on the computer.

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Improving supply chain risk assessment with artificial neural network predictions

Nisrine Rezki
Hassan First University of Settat, National School of Applied Sciences, Systems Analysis and Modeling and Decision Support Laboratory, BP 218, 26100, Berrechid, Morocco, n.rezki@uhp.ac.ma (corresponding author)
Mohamed Mansouri
Hassan First University of Settat, National School of Applied Sciences, Systems Analysis and Modeling and Decision Support Laboratory, BP 218, 26100, Berrechid, Morocco, mohamansouri@gmail.com

Keywords: supply chain risk management, artificial neural network, risk prediction, risk assessment, supply chain.
Abstract: Operational excellence serves as a cornerstone for the success of businesses,and effective risk management is key for minimizing disruptions, and ensuring business continuity. This paper proposes an innovative methodology that harnesses the power of machine learning in supply chain risk assessment to enhance the ability of organizations to identify, predict, and mitigate various risks that can impact their efficiency, effectiveness, and resilience. This study addresses the inherent subjectivity in human assessment which presents a significant challenges and potential biases in the evaluation process. Auditors, who play a crucial role in identifying and assessing risks within an organization's operations, often rely on subjective judgments influenced by their experiences, expertise, and personal biases. To mitigate this issue, we employ a deconstruction approach, breaking down risk factors into sub-factors, and leverage an Artificial Neural Network model as a predictive tool for accurate risk level predictions and enhanced assessment objectivity. Real-world data from a global automotive company specializing in wiring harnesses are utilized to train the Neural Network model, on a dataset of 2100 samples, exhibits good performance of risk prediction as evaluated by appropriate metrics such as Determination Coefficients and Mean Square Error. Overall, this research contributes to the advancement of risk management practices addressing the challenges of subjectivity in human assessment, to more objective by providing a reliable and data-driven framework that supports managers in strategic decision-making and fortifies supply chain operations through an early risk alarm, empowering organizations to proactively manage risks and achieve autonomy in effective risk management.

1 Introduction

Supply chain risk management (SCRM) has become more significant and attracted researchers' attention in comparison to previous years when less attention was given to risk management (RM).Furthermore, the complexity of production processes, huge quantity produced, uncertain demand, unexpected changes, and increase in various disruptions types cause substantial losses.[1] risks in the realm of SC management can be broadly categorized into two main types: strategic uncertainty and operational catastrophes. To illustrate the impact of such risks, consider the recent global phenomenon of the COVID-19 pandemic, which triggered a widespread scarcity of shipping containers and a significant rise in employee absenteeism, resulting in a substantial financial loss of billions of dollars. Additionally, the SC landscape faces inherent risks stemming from geopolitical events, like the Russia-Ukraine war, as well as challenges arising from the lack of synchronization between supply and demand. These factors, as highlighted by [2] contribute to the complexities and vulnerabilities encountered in SCM. Uncertainty, stochasticity, external disruptions, and risks can temporarily or durably impact the performance of the SC, where the need for implementing a well-defined RM process is crucial for mitigating exposure and minimizing disruptions, as it plays a pivotal role in effective RM strategies.

Today auditor's subjectivity can play a role in determining the risk level. It seems to be extremely difficult to assess risk, in the same manner, taking the case of two auditors working on the same organization cannot evaluate the risks equally, as the difference in professional judgment and experience influence their risk assessments and lead to subjective evaluations. The risk assessment subjectivity might cause various problems with severe monetary problems. It can lead to inconsistent evaluations of risks that make it challenging to compare and prioritize risks consistently. also, the subjectivity may lack transparency and fail to provide a clear justification of the factors influencing the risk levels which leaves excessive leeway for managers to understand and evaluate risks on their own in a way that will not interfere with the strategic plans for the company.

As for the impact of subjectivity in the risk assessment process, the primary objective of this research is to minimize the subjective nature of human assessments and achieve a more objective risk evaluation approach using Artificial Intelligence (AI) techniques that can help in addressing some of the subjectivity challenges in the risk assessment process by introducing more objective and data-driven analysis which reduces reliance on subjective

judgments and provides a more objective basis for risk assessment.

This study was carried out as the power of AI technologies its significant role in enhancing risk assessment processes due to several reasons and purposes such as the handling of large volumes of data more efficiently than humans and this is particularly important in risk assessment, where numerous variables and factors need to be considered. Further to the human judgment which sometimes can be influenced by biases, emotions. AI can provide consistent and objective analysis, minimizing the impact of human subjectivity and errors, leading to more accurate risk assessments and better-informed decision-making. In addition, AI models can leverage historical data to make predictions about future risks to anticipate potential risks and proactively implement strategies to mitigate them. In summary, AI's capabilities in data processing, analysis, accuracy, and real-time monitoring make it an invaluable tool for enhancing risk assessment across SC.

We propose a methodology with the goal of automating and standardizing the risk assessment process. By deconstructing the risk factors into distinct sub-factors, we systematically examined each component and analysed them collectively as a comprehensive feature vector. This vector serves as input for the machine learning (ML) model, where each numeric parameter conventionally represents the status of each factor in each sub-process. The used data was collected from a real automotive company operating in wiring harnesses worldwide, the type of industry was chosen as it's the pillar of the national economy, further to the widely of concern on SC disruption risk that has been considered in recent years by both business and academic practitioners. As the automotive SC has become increasingly difficult to manage and without effective RM it's almost hardly possible to see its operation normally. The International Automotive Task Force (IATF 16949) reports for 5 years were cleansed and converted to the predefined set of parameters as in Table 1. Audit reports are the result of an audit system assessing the quality management system of the company, verifying risk, defect prevention, process variation, and waste in the SC and production process.

Due to the scarcity of available data, a unique and highly confidential dataset was obtained, which played a pivotal role in training the ML model capable of accurately predicting risk levels within a SC. We trained the model on 80% of the collected data and 20% of a test set of the samples.

Ultimately, the integration of AI into SCRM has introduced new dimensions of complexity and opportunity. However, there are notable research gaps and challenges that require investigation, particularly in the areas of cleansing, integration, and validation of SC data. There are gaps and challenges in AI models that provide interpretable risk assessments, enabling SC professionals to understand risk behaviour. Additionally, gaps exist in AI models that can adapt and update in real-time based on changing risk environments. However, the current research on AI integration in SC lacks models capable of providing probabilistic risk assessments that account for uncertainties and ambiguities in SC risk scenarios.

Furthermore, research could investigate how AI models can effectively collaborate with human experts in making decisions related to SC risk. Additionally, addressing the gap of integrating human knowledge into AI models for SC risk assessment represents our contribution in this paper.

2 Literature review

Mathematical tools have played a pivotal role in the field of SCRM, enabling advanced analysis, modelling, and decision-making processes. Recently, research has begun to apply additional tools such as AI covering production risk management, and SC risk challenges in complicated environments, and in a specific part of the process.[3] classified the reviewed papers published between 2003 and 2013 on SCRM into four categories, definitions, types, factors, and methods for SCRM.Furthermore, methods are classified for risk management as either qualitative or quantitative depending on their core operations, such as risk detection, assessment, reduction, and monitoring.

[4] centres their investigation on the implementation of intelligence-based tactics to improve the management of SCRs and strengthen overall resilience. The outcomes of their study offer valuable perspectives on the existing landscape of SCRM methodologies and the efficacy of resilience approaches across various sectors. [5] examined the influence of digitization, big data, and Industry 4.0 on their role in mitigating the cascading impact of SC risk. Nevertheless, the researchers highlighted the necessity for further investigation before introducing decision-support systems that incorporate ML and agent algorithms to enhance the optimization of stochastic systems.[6] present a comprehensive model that leverages big data in the planning and process control domains to effectively manage SC risks, this approach involves collecting extensive data from various sensors, both internal and external, which are then meticulously analysed to generate detailed reports for decision-makers, enabling them to make informed decisions regarding SC redesign.

In their research, [7] demonstrate the potential of utilizing SC data analysis not only for pursuing and managing supply risks but also for enhancing supplier performance. This approach empowers global SCs to proactively respond to SC risks rather than adopting a reactive approach, enabling them to take initiative in mitigating potential disruptions and ensuring a more resilient and efficient SC ecosystem. However, their study does not mention a predictive model but only a practical data presentation. Another study by [8] offers a conceptual framework for SCRM using ML techniques and big data without evaluating and implementing the framework, their conclusion suggests that incorporating AI in SCRM processes can potentially enable the discovery of new knowledge. This new found knowledge, when combined

with the expertise of decision-makers, has the potential to facilitate optimal decision-making in SCRM processes.

Existing literature reveals that various AI techniques exhibit partial applicability in different contexts of risk management in various stages of the SC. One of the most used AI techniques in various levels of production management is the ANN applied in the area of forecasting, demand planning, inventory management and risk assessment. As the efficacy of forecasts is contingent upon the accuracy of predictions, scholars have redirected their focus to the area of fast-changing data combined with traditional forecasting and AI techniques to generate more accurate predictions of forecasts to improve demand planning.[9] studied the ability of ML in generating more accurate forecasts in comparison to traditional methods.[10] suggest a methodical managerial strategy for investigating the correlation between AI and the bullwhip effect ,their research provides scholars and managers with a fundamental platform for advancing theories on how to alleviate the fluctuations in SC caused by the bullwhip phenomenon. [11] In ordering management ML is used to establish an optimal ordering strategy in several SC levels to evaluate order priority and manufacturing order priority. [12] create an enhanced version of grey neural networks, which can assist businesses in making more accurate forecasts regarding market demand following disruptions in transportation. Subsequently, they conduct an empirical study to validate the practical viability of this improved mode.[13] used a combination of ANNs and auto-regressive integrated moving average (ARIMA) models to forecast the requirements for blood platelets. The intention behind their approach is to minimize uncertainties within the SC associated with blood platelet demands. [14] Their inquiry offers a practical instance where they predict monthly demand for three blood components through the utilization of ANNs. The outcomes of their analysis illustrate that ANN models outperform ARIMA models in the realm of demand forecasting.

From the reviewed existing literature on the AI application in SC, we can see that AI techniques have been used throughout the SC, neural networks have shown their results also in problems related to supplier selection process. [15] In their study, they employed ANN to address the primary challenges associated with case-based reasoning within supplier selection. This was done with the intention of enhancing both the precision in revising stages and the efficiency of the supplier selection process.[16] Their paper aims to put forward a hybrid strategy that melds the Z-number Data Envelopment Analysis (DEA) model with the ANN to improve the process of selecting resilient suppliers. The objective is to refine supplier selection by incorporating two key aspects: an efficiency-centered assessment through Z-number DEA and the predictive potential of ANN, with particular emphasis on the resilience of suppliers.

Enhancing strategies for managing the movement of goods within production logistics systems is a significant aspiration within contemporary industries. Consequently, the investigation of inventory control methods holds exceptional significance. [17] In their proposed methodology, they adopt a state-feedback neural network controller to determine the ideal order quantity, accounting for uncertainties in the deterioration process and adhering to the FIFO issuing policy. [18] develop AI forecasting models for better forecast and inventory management improvement.

[19] Their study elucidate the evolution of deep learning (DL) and ML concepts within the framework of devising a plan for identifying and evaluating SCRs. Their outcomes indicate a notable enhancement in the ability to forecast whether a shipment is destined for export, outperforming numerous other pre-existing ML methodologies.Scholars have increasingly promoted the adoption of Industry 4.0 (I4.0) solutions as a strategy to mitigate supply chain disruptions (SCDs) [20], especially in light of the challenges exposed by the COVID-19 pandemic. In their research [21],they built upon prior work in I4.0 and SCRM, creating 13 projections that delineate how I4.0 technologies will shape Supply Chain Resilience (SCRES) by 2030. Their study evaluates the potential of I4.0 in enhancing SCRES within a post-COVID-19 context. As well,[22] their study seeks to elucidate the role of AI applications in supporting Operations and Supply Chain Management (OSCM) processes, as well as to pinpoint the advantages and challenges associated with their integration. The findings underscored the capacity of AI techniques in OSCM to enhance the competitive edge of companies by diminishing expenses, shortening lead times, and enhancing service levels, quality, safety, and sustainability.[23] examined how AI techniques can enhance SCM through the execution of a structured analysis of existing literature.

In this study, we carefully selected the primary risk factors based on their direct relevance to SC and production organizations. Specifically, our focus was directed toward the critical and potential factors that influence the risk level during auditors' evaluation in each IATF audit. These selected risk factors encompass common types of risk in manufacturing, supply, transport, demand, and information, considering their external and internal interfaces. This selection process served as an initial foundation for creating an additional resource aimed at defining and categorizing the deconstructed risk factors in more detail. The objective is to achieve more accurate risk evaluation from the auditors by placing more emphasis on the sub-factors and enabling a precise assessment of risk factors integrating an ANN model in RM process flow as in Figure 1.

3 Methodology

3.1 Risk management process flow with ANN integration

In Figure 1, we detail the methodology employed to integrate an ANN model in the RM process for risk prediction purpose, to mitigate and reduce SC disruptions and control risks in advance. The initial phase involves the

identification of potential risks that could impact the organization, followed by risk factors deconstruction into sub factors to get more precision on the risk elements. The identified risk factors are evaluated in terms of their severity, impact, and probability. Gathered and cleaned data is used to train the model to predict risk level of the potential risks that may disrupt the SC, foreseeing risks helps in prioritizing and providing strategies to mitigate the risks, decisions can vary in their approach, ranging from accepting the entire risk without implementing any actions for low-risk events, to implementing a series of preventive measures for high-risk events. A regular RM process review ensures that new potential and suspected risks are remains up-to-date and introduced in the model to be verified and assessed if they occur. Figure 1 depicts the risk assessment flow integrating the ANN model.

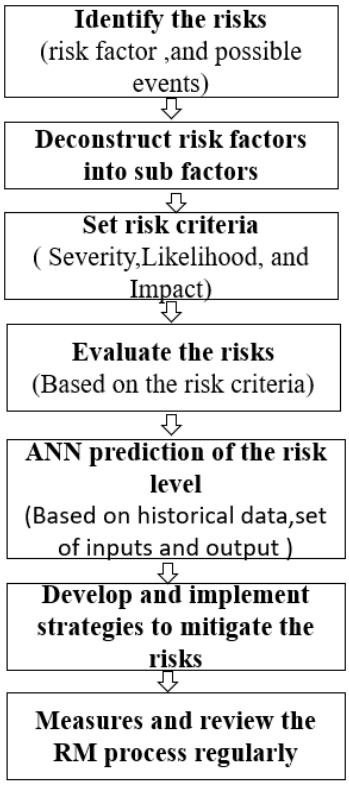

Figure 1 Risk assessment process flow with integration of ANN

3.2 Neural network model for risk assessment

In order to initiate the development of our proposed methodology of applying ML tools in SC risk assessment an exhaustive list of parameters was selected, covering most of the operational risks, from a reel audit report of an automotive company that covers the results of IATF certification following regulations and automotive standards. We focused on a research sample consisting of 30 automotive production sites operating in wiring harnesses word wide. Findings and audit results of 5 years were converted in accordance with the selected operational risks which were observed as parameters and a major risk of the selected automotive company. The selected parameters of the model which represents the risk factors in this research are mainly based on their relevancy to the automotive SC. The selected risks cover external and internal risks in different node of the SC, covering supply,demand,manufacturing,process,financial,macro,inventory,information,payement and transport risks. Moreover, the inputs include the results and feedback from different OEMs (Original Equipment Manufacturers) and tier 1 suppliers. Audit reports were employed as the dataset containing risk factors and served as the input layer for the ANN used in training the predictive model for future risk estimation.The model underwent training using a dataset consisting of 2100 samples. The risk data is highly classified business information that is publicly unavailable. Attaining the data from an automotive manufacturing company for the purpose of risk prediction was a challenging goal and a unique opportunity to gain insights using confidential business information.

Table 1 List of parameters

No	Parameter	Literature
1	Leadership and commitment	[24,25,26,27,28]
2	Products/services requirements	[29]
3	Performances evaluation	[30]
4	Continuous improvement	[31]
5	Demand Uncertainty/Variability	[32,33]
6	Manufacturing risk	[22,34]
7	Delivery/Transport delay	[35]
8	Supplier dependency	[36]
9	Information system	[37]
10	Financial risk	[38]
11	Inventory control	[39,40,41]
12	Payment control	[42]
13	Purchase orders	[43]
14	Macro risk	[44]

We converted the findings of 150 IATF audit reports, produced in 2018-2023, in accordance with the exhaustive selected risk factors from the IATF standards that are most relevant for the selected automotive company, specific and unique risk factors were neglected as their low probability of occurrence in the results of the audits. The focus was on the most relevant and probable risk factors assessed and reported during several audit reports with a high impact on the operational business.

Auditor's risk assessment practice is an investigation based on experience and risk knowledge way of saying and assessing the risks, auditors do not have a well-defined result for each parameters deviation linked to the IATF standards and regulations basics, parameters are not evaluated in the same way for all auditors. In order to get an easy, objective, quantitative, and accurate risk assessment each of the selected risk factors is broken down

into their sub-factors and the results are fit as an input vector to train the ML model.

Regarding the numerical evaluation of the audit results for each assessed parameter, auditors assign a risk level of high, low, or medium to indicate the severity of the risk associated with that parameter. However, it's worth emphasizing that the final audit results are subjective assessments made by the auditors based on their judgment and interpretation of the assessment.

The deconstruction of risk factors into sub-factors is crucial to achieve a more accurate assessment of the selected parameters. To accomplish this, each sub-factor of every parameter was assigned a value based on its performance level. A value of 0 indicates a neutral level of compliance with standards and regulations, -1 indicates a weakness in adhering to the standards and regulations, and 1 indicates an appropriate level of compliance. Additionally, each compiled report was assigned a risk probability value, ranging from 0 to 1, representing the likelihood of risk for each company. To obtain an assessment for each specific evaluated risk and gain a comprehensive understanding of the most influential factors in the overall risk probability assessment for each company, it is important to identify the key impacting factors. This knowledge is particularly valuable as the reports are derived from the same company with consistent standards applied across various sites.

While it may not be immediately evident, the selection of parameters from the IATF 16949 standard, as related to the topics in Table 1, is undertaken with a specific aim. These parameters are chosen based on their alignment with factors derived from quality management standards. These factors hold essential roles in establishing the quality management requirements expected of automotive manufacturers and suppliers. This research aims to assess the automotive industry's capability to manage risks. The careful organization of these selected parameters is designed to evaluate an organization's risk exposure and compliance with the IATF standard. By considering these factors collectively, we contribute to a comprehensive understanding of their impact on organizational performance and overall success (Table 2).

Table 2 Selected parameter is derived from a set of sub-parameters

Leadership and commitment were compiled from the following sub-parameters	**Products/services requirements were compiled from the following sub-parameters:**	**Supplier dependency**	**Delivery/Transport delay**
(1) is the company taking responsibility for the effectiveness of the quality management system?	(1) Is the communication with customers include: (a) the provision of information relating to products and services? (b) the treatment of consultations, contracts, or orders, including amendments?	Alternative supplier in case of major supplier stoppage	Natural Accidents (Fire, Earthquake)
(2) Are the quality management system requirements integrated into the organization's business processes?	(c) obtaining feedback from customers regarding products and services, including their complaints?	Long-term relationships with reliable suppliers	Abnormal Accidents(Manmade Disaster/Terrorism attack)
(3) Is the organization promoting the use of the process and risk-based approaches?	Any applicable legal and regulatory requirements?	Supplier monopoly	Packaging and shipping quality issues
(4) Is the organization incentivizing, guiding, and supporting persons to contribute to the effectiveness of the quality management system?	(2) Does the organization use appropriate means to identify output elements where it is necessary to ensure compliance with products and services?	Selection of the wrong partner	Safety stock unavailability
(5) Does the organization promote improvement?	(3) Does the organization preserve the output elements during production and service provision to an extent sufficient to ensure compliance with the requirements?	Low technical reliability	Custom clearances
6) The priority of increasing customer satisfaction is maintained by the organization?	NOTE: The preservation may include identification, handling, contamination control, packaging, storage,	**Information system**	Transportation breakdown
7) Are the customer's requirements understood and met?		Information infrastructure	Damages in transport
		System Integration	No transport solution alternatives
Payment control		Information transparency	Lack of outbound effectiveness
		Information delays	
		Compatibility in IT platforms	**Purchase orders**
		Back up procedures	Purchase process control through the ERP system
		Demand Uncertainty/Variability	Purchase procedures and documents follow up
		Forecasting errors	
		Market change	**Inventory control**
		Bullwhip effect distortion	Regular warehouse inspection
		Continuous improvement	Warehouse inspection according to procedures
		Does the organization continuously improve the relevance, adequacy, and effectiveness of the quality management system?	Inventory system update
			Financial risk
		Does the organization consider the results of the analysis and evaluation, as well as the outputs of the	Exchange rate fluctuations
			Loss of contrast
			Market growth
			Profit margin
			Price fluctuations

Presence of sufficient control mechanisms ensuring alignment between a certificate of receipt and the corresponding invoice. Appropriate measures in place to ensure effective control over payments **Performances evaluation** (1) Does the company determine: (a) what needs to be monitored and measured? (b) the monitoring, measurement, analysis, and evaluation methods to ensure the validity of the results? c) when monitoring and measurement should be carried out? 2) Customer satisfaction: Is the organization actively monitoring and assessing customers' perceptions regarding the extent to which their needs and expectations are being met? Does the organization analyze and evaluate the level of customer satisfaction?	transmission, or transport and protection. **Manufacturing risk** Unstable manufacturing process Employee accidents Insufficient maintenance Lack of experience/training Production capabilities Product inflexibility Machine breakdown, Quality problems Design changes Technological changes	management review, to determine if there are needs or opportunities to consider as part of continuous improvement?	**Macro risk** Political instability Economic downturns External legal issues Sovereign risk Regional instability Social and cultural grievances Natural Accidents (Fire, Earthquake) Abnormal Accidents(Manmade Disaster/Terrorism attack)

3.3 ANN model application on real database

A stable database was formed from the audit reports conducted for 5 years to create a consistent database to train the model. For example, we chose 2 IATF audits reports of 2 sites audited in 2022. Table 3 shows how the risk factors and their risk sub-factors were converted into a table of parameters as a sum of each graded {-1,0,1} parameter.

The probabilities by the auditors were given by text that reflects the level of the risk as low, medium, or high (Table 3). These are transformed to represent low: [0 – 0.3], medium: [0,4 – 0,7], and high: [0,8 – 1]. In the example, Site 1 was assigned a probability value of 0.3, indicating a relatively low level of risk. Conversely, Site 2 and Site 3 received probability values of 0.4 and 0.5, respectively, indicating moderate levels of risk.

Table 3 Risk factors and their risk sub-factors

Parameters	Site 1	Site 2	Site 3	Details
Continuous improvement	1	1	1	Site 1,2,3: The organization has a high adequacy and effectiveness of the quality management system, continuously improving. The organization has a good consideration for the outputs of the management review to determine needs and opportunities for continuous improvement.
Leadership and commitment	1	0	-1	Site 1: The company has a high responsibility for the effectiveness of the quality management system and requirements are integrated into the organization's business processes and customer's requirements as well as the applicable legal and regulatory requirements are determined, understood, and met continuously in a good level. The company maintains customer satisfaction and promotes improvement. Site 2:

				The company has a responsibility for the effectiveness of the quality management system and requirements are integrated into the organization's business processes. Customer requirements are determined and understood, regulatory requirements are not determined, and either. The company maintains the customer satisfaction and promotes improvement. understood. Site 3: The company has a very low responsibility for the effectiveness of the quality management system and requirements are not integrated into the organization's business processes and customer requirements are not determined and either understood. Customer satisfaction is not met and improvement is very low
Total risk probability	0.3	0.4	0.5	

4 Results and discussion of the ANN model

ANNs are crucial in ML and AI, mimicking biological neural structures. ANNs consist of interconnected layers of artificial neurons that process input, learn from data through weight adjustments, and excel in tasks like pattern recognition and prediction across domains. This learning ability empowers researchers to create intelligent systems capable of understanding complex phenomena.

In the context of this work, the dataset comprises 2100 samples, each consisting of 150 observations, characterized by 14 parameters with values {-1, 0, 1} and a score within the range [0, 1] representing total risk probability. This distinctive dataset configuration necessitates ANNs to master regression tasks. To enable a robust evaluation, the data is partitioned into training (80%) and testing (20%) subsets. Additionally, the model's performance evaluation employs k-fold cross-validation, which partitions the dataset into subsets for both training and testing, yielding reliable performance assessments across multiple iterations.

The architecture of the neural network is thoughtfully designed through hyper-parameter tuning, with the number of hidden layers strategically selected based on problem complexity. The specific configuration comprises seven layers, commencing with 14 inputs and culminating in a single output, employing the sigmoid function to ensure values within the [0, 1] range. The choice of 100, 80, 70, 60, and 50 neurons across hidden layers is meticulously calibrated to optimize model performance. The model's optimization employs Adam as the optimizer and Mean Squared Error as the loss function, implemented using TensorFlow 2.10.0 library.

After inputting the data into the network, we employed two suitable evaluation metrics, Mean Squared Error (MSE) and R^2 (coefficient of determination), to assess the model's predictive performance for both cases. Case N1 involved predicting the overall risk probability for each company, while case N2 focused on predicting the risk probability for individual factors across all company sites. These evaluations helped us identify the effectiveness of the model in predicting the total risk probability and determining which factors have the most significant impact on the company's overall risk profile.

In Figure 2, the Mean Squared Error (MSE) values between the desired target values and estimated model outputs for training data are plotted against different epochs for case N1. The horizontal axis represents the progression of the model over time, while the vertical axis represents the MSE values, which range between 0.002 and 0.004. The graph shows that the MSE values decrease over epochs, indicating that the model is improving its predictions and reducing errors during the training phase.

Similarly, in Figure 3, the MSE values for testing data are depicted over different epochs for case N2. The graph illustrates the performance of the model in predicting the risk probability for each factor across all company sites. The MSE values also exhibit a decreasing trend, indicating that the model's predictions are becoming more accurate and closer to the desired target values during the testing phase.

Overall, the observed trends in Figure 4 demonstrate that the neural network model is performing well, continuously learning from the data, and effectively reducing errors over time, leading to achieving the lowest MSE values possible.

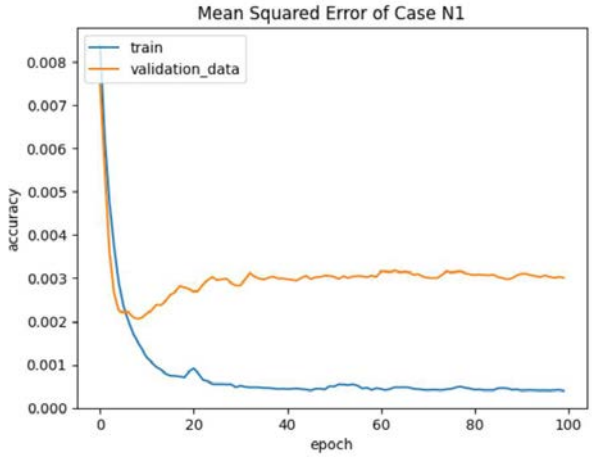

Figure 2 Mean Squared Error of case N1

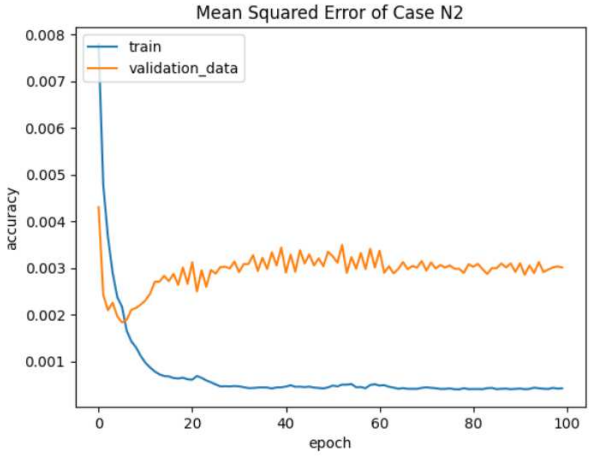

Figure 3 Mean Squared Error of case N2

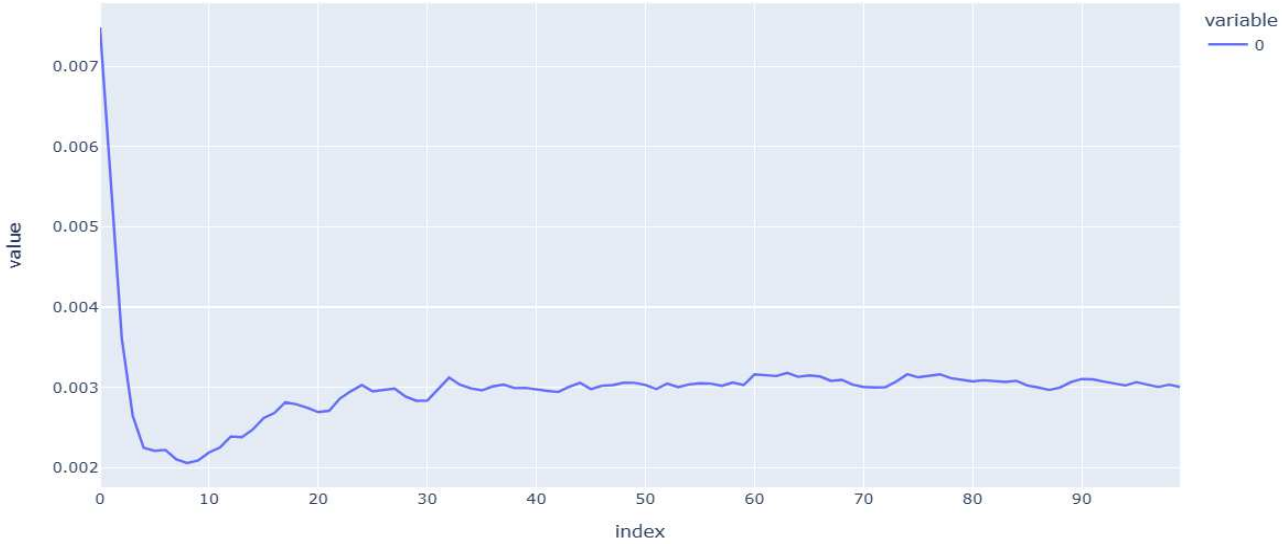

Figure 4 Mean Squared Error Trend over time of case N1

In Figure 5, the determination coefficient (R^2) values are plotted against different epochs to measure the goodness of fit for the training data. The horizontal axis represents the progression of the model over time, while the vertical axis represents the R^2 values, ranging from 0 to 1. The graph shows how well the model predicts the outcome by indicating the proportion of variability explained by the model. As the epochs progress, the R^2 values increase, indicating that the model's predictions are becoming more accurate and explaining a larger proportion of the variance in the variables.

Similarly, in Figure 6, the R^2 values for the validation data are depicted over different epochs. The graph illustrates how well the model generalizes its predictions to new, unseen data. As the epochs progress, the R^2 values for the validation data also increase, indicating that the model is performing well in capturing the underlying patterns and variability in the data.

Overall, the observed trends in both Figure 5 and Figure 6 demonstrate the improvement of the model's predictions over time, as indicated by the increasing R^2 values. These results indicate that the model is effectively capturing the relationships between the variables and explaining a significant proportion of their variance, leading to a good fit between the predicted outcomes and the actual data.

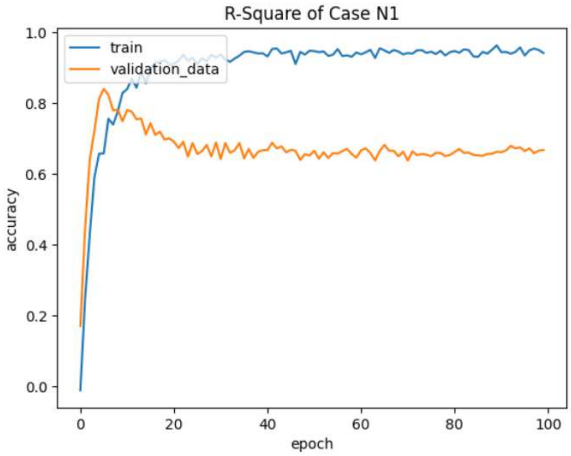

Figure 5 R-Squared of case N1

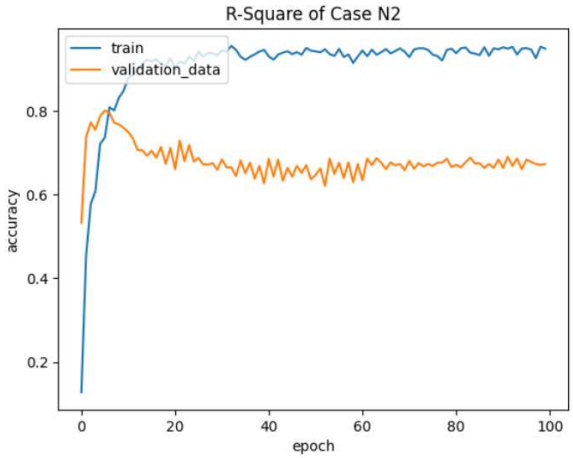

Figure 6 R-Squared of case N2

For both cases, the R-squared values for the model's predictions range between 0.5 and 0.85. This indicates that the model is able to explain a significant portion of the variance in the dependent variable. The proximity between the training and validation R-squared values suggests that the model's performance is consistent across different datasets, indicating its generalization ability.

In case N1, the developed model demonstrates an explanatory power of approximately 85% in terms of the variance in the dependent variable. This means that the model is able to account for 85% of the variability observed in the risk assessment. However, there is still 15% of the variance that remains unexplained by the model.

In case N2, the model shows an explanatory power of approximately 70% in relation to the variance in the dependent variable. This indicates that the model can explain 70% of the variability observed in the risk assessment. However, there is 30% of the variance that remains unexplained by the model.

Overall, the increasing trends of the R-squared values and their proximity to 1 demonstrate the model's ability to capture and explain a substantial portion of the variance in the data, indicating its effectiveness in predicting the outcomes for both cases.

It's important to note that the remaining unexplained variance may be attributed to various factors such as inherent complexity in the risk assessment process, external influences, or other unaccounted variables that were not included in the model. The aim of the model is to capture as much of the variability as possible and provide a standardized and objective assessment of risk, but there will always be some level of unexplained variance.

To ensure that the developed ANN model avoids overfitting or overtraining problems, two key parameters need to be carefully adjusted: the number of epochs and the number of neurons in each hidden layer.

In this study, the optimum size of epochs and the appropriate number of neurons for each hidden layer were determined through experimentation and evaluation. The goal was to strike a balance where the model achieves good performance without overfitting the training data. For example, when comparing the performance of the model with 100 epochs to the model with 150 epochs, it was observed that increasing the number of epochs led to a decrease in performance for both statistical measures: R-squared (with a higher percentage of unexplained variance) and MSE (with greater distance between the training and validation test values).This indicates that the model with 100 epochs achieved better results in terms of capturing the variability in the dependent variable and minimizing the prediction errors. It suggests that increasing the number of epochs beyond a certain point may lead to overfitting, where the model becomes too specialized in the training data and fails to generalize well to unseen data.

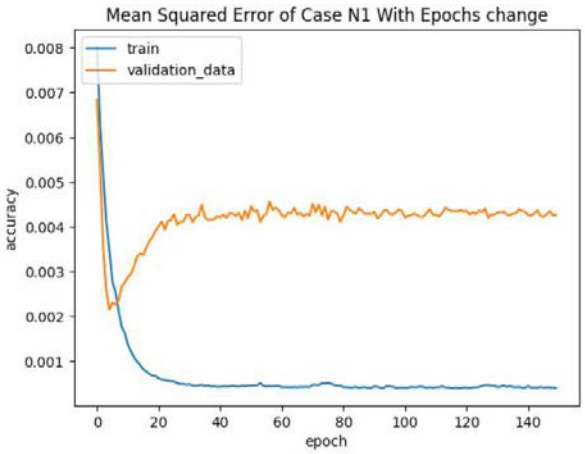

Figure 7 MSE of case N1 with epochs change

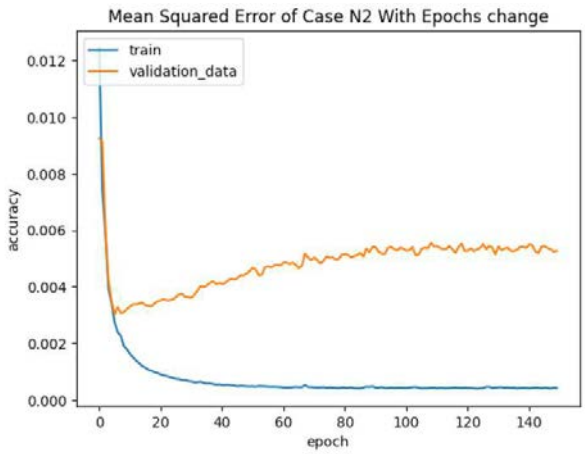

Figure 8 MSE of case N2 with epochs change

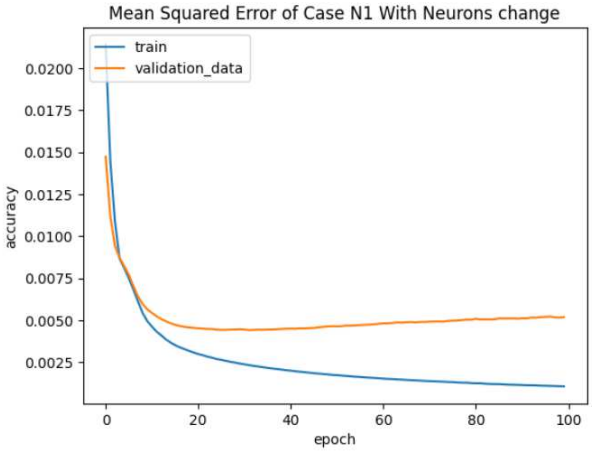

Figure 9 MSE of case N1 with neurons change

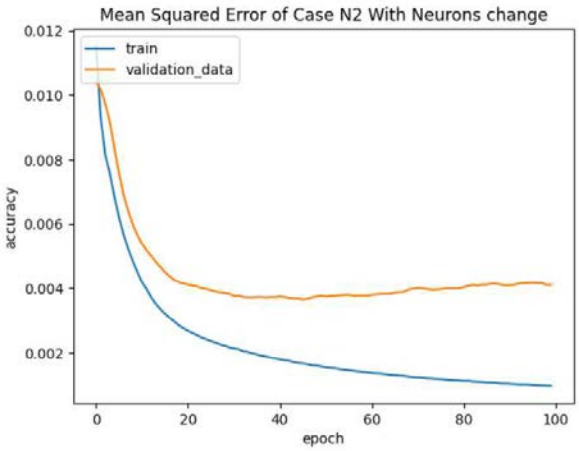

Figure 10 MSE of case N2 with neurons change

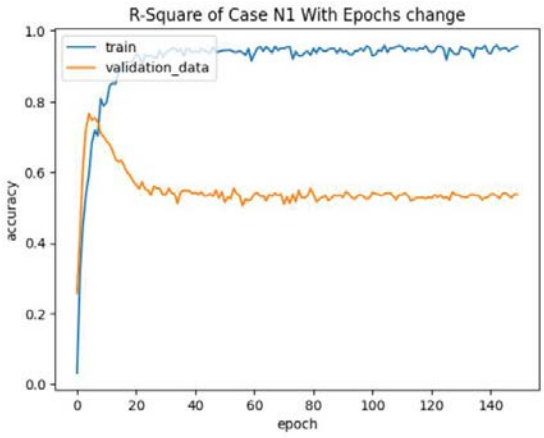

Figure 11 R-Square of Case N1 with Epochs change

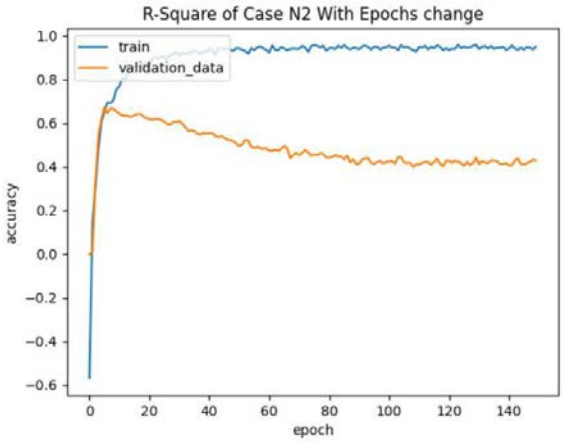

Figure 12 R-Square of Case N2 with Epochs change

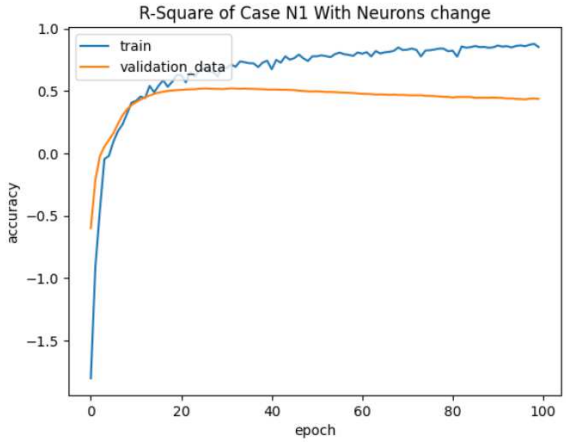

Figure 13 R-Square of Case N1 with Neurons change

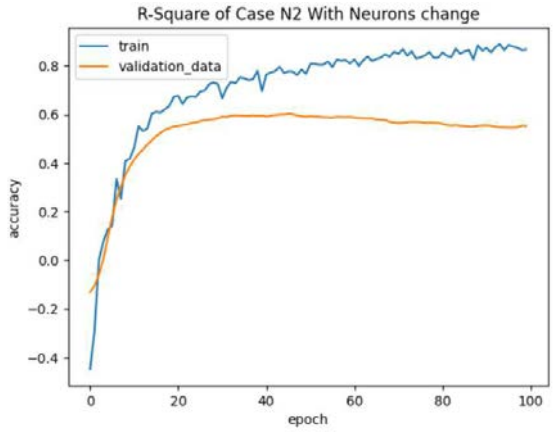

Figure 14 R-Square of Case N2 with Neurons change

To optimize the model's performance and improve R-squared and MSE, adjustments were made to the number of epochs, (Figure 7, Figure 8), and the number of neurons in the hidden layers. By fine-tuning these parameters, we aimed to achieve higher values of R-squared and lower values of MSE.Through this adjustment and parameter tuning process, it was determined that R-squared and MSE can vary significantly depending on the number of epochs and neurons in the hidden layers. The model's structure, including the configuration of hidden layers and the number of neurons, has a direct impact on the predicted values and overall performance of the model. The predicted values of the model align with the scale range of the training dataset, as shown in Table 4. This implies that the model's predictions are consistent with the data it was trained on. Specifically, the predicted values consistently fall in the middle of the scale range, indicating that the predicted risk level aligns with the risk level observed in the trained dataset. Furthermore, the computed risk probabilities generated by the model exhibit a good fit with the assessed risk levels determined by the auditors. This positive indication confirms that the model has successfully learned and captured the patterns and relationships present in the training data.

In Figures 9-14, we explored the effect of decreasing the number of hidden layers and neurons in the ANN model. Specifically, we transitioned from a model architecture with 5 hidden layers and 100, 80, 70, 60, and 50 neurons for each hidden layer to a simpler architecture with only 1 hidden layer consisting of 50 neurons.

The observed trend in the performance of the model is that as we decreased the number of hidden layers and neurons, there was a decrease in performance metrics such as R-squared and MSE. This is reflected in the greater distance between the training and validation values, indicating a higher level of prediction errors.

The alignment between the predicted values and the actual risk levels, as well as the confirmation through evaluation metrics, provides confidence in the model's ability to generalize and make accurate predictions for unseen data. It suggests that the model has effectively learned from the training data and can apply its understanding to new instances, enabling it to provide reliable risk-level assessments.

Table 4 Predicted and trained values risk level comparison

Predicted Values	Probability Range	Predicted Risk Level	Trained Values	Predicted Risk Level
0.58	[0.4, 0.7]	Medium	0.6	Medium
0.52	[0.4, 0.7]	Medium	0.6	Medium
0.41	[0.4, 0.7]	Medium	0.5	Medium
0.40	[0.4, 0.7]	Medium	0.4	Medium
0.33	[0.0, 0.3]	Low	0.3	Low

5 Conclusion

The overarching goal of this study was to establish a methodology serving in the risk assessment process in the industry. Our suggested work tries to formally conceptualize the risk assessment process practice consisting to objectify the risks instead of their subjectivity, as the interviews conducted with expert auditors indicated a prevailing absence of educational programs or professional accountability standardizing the way of assessing the risk, this lack of formal methodology is one of the main factors of subjectivity leading auditors to look at risks differently. The subjective nature of auditor risk assessment introduces uncertainty in risk measurement. To address this issue, we proposed a measurable risk approach based on risk levels assessed by the auditors. Risks were categorized into specific ranges and assigned a percentage of occurrence. This quantifiable approach aims to provide a more objective and standardized assessment of risk, reducing the inherent subjectivity in the evaluation process and making more precise and consistent risk measurement. The suggested method comprised the entire risk assessment process, from engaging the firm with a clearly defined set of criteria for evaluation, which were deconstructed to their sub-risk factors, for an accurate risk evaluation instead of a general risk factor assessment, then utilized as a feature vector for the input layer of the neural network model which return and predict a computed risk probability aiming to centralize the risk in its perimeter. The used data was collected from a real automotive company presented word

wide and operating in the same activity sector, audit reports of 5 years served as input of the model they were cleansed and transformed from textual written into the predefined deconstructed risk factors, the selected data is resulted in a small, confidential but a highly valuable data.

Indeed, the implementation of the neural network model in risk assessment can significantly reduce the impact of auditor subjectivity and improve the reliability and consistency of risk assessment. The continuous learning process of the neural network allows it to improve its predictions over time by reducing errors and adjusting its internal parameters. This leads to achieving acceptable Mean Squared Error and R-squared values in both cases N1 and N2.

The acceptable MSE values indicate that the predicted risk probabilities are close to the auditor's risk level assessment, values range between 0.002 and 0.004, the MSE values decrease over epochs, indicating that the model is improving its predictions and reducing errors during the training phase. Furthermore, the model's performance in terms of capturing the variability in the dependent variable is reflected in the R-squared values by achieving approximately 85% and 70% respectively for case N1 and N2.

By having the predicted risk values within the scale range, it provides a means to evaluate and quantify risk using the model's predictions. This enables stakeholders to make informed decisions based on the risk assessment results generated by the neural network model. The alignment between the predicted values and the risk level scale enhances the model's usability and applicability in real-world risk assessment scenarios. The method we recommend has the capability to provide practical benefits as a tool for companies and organizations. that are looking to evaluate and manage their risk as by addressing the subjectivity in risk assessment, organizations can benefit from more reliable and consistent risk assessments, which can aid in strategic decision-making and enhance the overall risk management process.

However, the study is not free of limitations. The research findings strongly support the notion that ML is highly effective in both reducing the time needed for risk assessment feedback and improving the accuracy and objectivity of the risk assessment itself. The returned outputs from the trained model allow us to take the model as a basic step and attempt to expand it by introducing inputs from various sensors providing data from different points. The used dataset comprised 150 IATF audit reports for a defined automotive company, it might be the case that other companies from the same activity sector provide different audit results which will differentiate the dataset aspects as well as the outputs that will also be changed. Furthermore, the number of selected parameters may be changed in case of several companies' dataset presence as each company has a strategy and policy to manage its business. Secondly, the process of transforming the data from written reports into categorized parameters involves a certain degree of manual work that needs to be formed in a manner to get results automatically to speed up the process of collecting data, in addition to the subjectivity in evaluating the risk level assessed by the auditors to transform it to a risk percentage, this assessment may keep a degree of subjectivity, it would be preferable to have this assessment by the auditors instead of their general judgment. Moreover, exploring the relationships between specific risk factors that may have a low individual risk but still influence the overall risk in the SC should be a focal point for future directions. Additionally, conducting interviews with auditors to gather their insights and feedback on the methodology would enable adjustments to the model based on their needs and help address any subjectivity in the risk assessment process. Taking these perspectives into account, we will consider and incorporate them into our future research endeavours.

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