IOSR Journal of Business and Management (IOSR-JBM)
e-ISSN:2278-487X, p-ISSN: 2319-7668. Volume 27, Issue 4. Ser. 4 (April. 2025), PP 10-18
www.iosrjournals.org

Measuring Productive Efficiency In Forklifts: A Systematic Literature Review

Fabiano Nunes, Cristine Hermann Nodari, Jose Antonio Valle Antunes Júnior
(Pure Sciences And Technology Institute / Feevale University, Brazil)
(Academic Master's Degree In Administration / Feevale University, Brazil)
(Production And Systems Engineering Graduate Program / Unisinos University, Brazil)

Abstract:
Background: *This study performs a Systematic Literature Review (SLR) to analyze models and methods for measuring efficiency in forklifts, highlighting gaps in existing knowledge. The research aims to broaden the understanding of the topic, identifying either models or methods applied in the operational management of this equipment in distribution centers.*
Materials and Methods: *The methodology followed rigorous protocols, including inclusion and exclusion criteria, to review articles published between 1960 and 2024 in the Scopus and Web of Science databases.*
Results: *The results indicate that traditional measurements are limited to indicators such as hours worked and utilization rates, revealing the absence of consolidated models that consider broader metrics, such as environmental impact and productivity. Studies analyzed demonstrate that multicriteria methodologies, such as FUCOM and WASPAS, are effective in selecting and evaluating forklifts, contributing to more assertive decisions, but are not sufficient to determine the operational efficiency of a forklift.*
Conclusion: *This research highlights the need for new models that integrate contextual variables such as loading times and equipment downtime analysis to maximize forklift operational performance. As a contribution, the study provides a detailed overview of existing approaches and suggests future research focusing on emerging technologies such as IoT and artificial intelligence to improve logistics efficiency.*
Key Word: *Productive efficiency; Forklift; Efficiency; Measurement; Systematic Literature Review.*

Date of Submission: 03-04-2025 Date of Acceptance: 13-04-2025

I. Introduction

The logistics sector plays an essential role in supply chain management (SCM), connecting distinct stages of production, storage, and distribution. As the foundation of this process, warehouses balance supply and demand, reduce costs, and increase operational visibility. Logistics equipment, such as forklifts, are crucial to optimizing material pooling and improving operational efficiency, especially in environments where automation is still limited. The efficiency of forklifts directly affects warehouse performance, while [1] highlight that a careful selection of smart equipment can reduce operational costs and improve operational punctuality and accuracy [1], [2]. Forklifts are used for transportation applications where flexibility and high turnover rates are the main requirements [3], [4].

With the advancement of innovation from digital technologies, the criteria for greater efficiency in warehouses and distribution centers have grown, driven mainly by e-commerce and the rise of large retailers. However, challenges such as labor shortages and limitations of conventional equipment, such as manually operated forklifts, make it difficult to meet market demands. In addition, activities such as picking, order separation, and shipping require constant monitoring to ensure efficiency and competitiveness [5], [6]. The role of warehouses goes beyond storage, providing supply chain integration centers and promoting productivity gains. Despite the growing interest in advanced equipment, such as trilateral forklifts, their market potential is still underutilized. To face these challenges and meet the growing expectations of consumers and companies, it is necessary to invest in strategic operational planning, automation, and operations specialization technologies regarding the flows and processes in these operations, especially about material handling equipment [2], [7]–[11]. Material handling equipment directly determines the efficiency of operations in a Logistics Distribution Centers (LDC) [12]–[15] Therefore, it is necessary to analyze material movements using forklifts [16]–[22] since forklifts are the most widely used mobile resources for moving materials in distribution centers and warehouses [18], [22]–[25]

Due to this complexity and the future scenario of these operations, the need for the evolution of LDCs and the challenges of productivity and efficiency increase [26]–[28], so new technologies and new methods must be considered in the necessary changes to logistics [29], [30]. The topic of measuring efficiency in forklifts was presented by Nunes [9]in a study of indicators applied to operations in Brazilian Logistics Distribution Centers. In this research, the scarce measurement of productive efficiency in these environments was observed, and no indicators that guide the measurement of forklift efficiency were found in the sample. The study only presents the measurement of utilization through the measurement of hours worked and collected by hour meters installed in such equipment [9] From this perspective, this article aims to develop a Systematic Literature Review (SLR) on the topic of measuring efficiency in forklifts. This SLR aims to provide an image of the publications in the area and to facilitate the process of understanding the topic [31]–[33]. Most of the research that addresses forklift efficiency in the literature focuses on the design and operational characteristics of the forklift, facility layout, and storage and routing policies [34]. This SLR aims to verify the research carried out on the topic of asset operational efficiency and its results in order to analyze the existence of models, methods, or frameworks that guide the measurement of this concept in forklift operations. This article is structured as follows: the next section provides the research methodology followed by the findings. Then, the discussion and final remarks are presented to discuss the contributions of the research, limitations, and areas for future research.

For this research, a work method was developed based on Morandi and Camargo [31] for the execution of the SLR (Figure 1). In step 1, in defining the central research theme, Nunes [9] research addressed the indicators used in the management of efficiency in forklift fleets in Brazilian distribution centers. In this research, we observed that the companies surveyed do not measure the efficiency of forklifts in their operations, and no model for measuring forklift efficiency was found in the literature. Studies present the measurement of the use of this equipment by measuring the hours worked, which are collected by hour meters attached to this equipment. Thus, the need to measure the efficiency of this equipment is a research gap that needs to be broadened in the discussion on the topic of material handling equipment. Thus, the central question that guides this SLR[35] is how the measurement of efficiency, utilization, or productivity is applied in measuring the efficiency of forklifts.

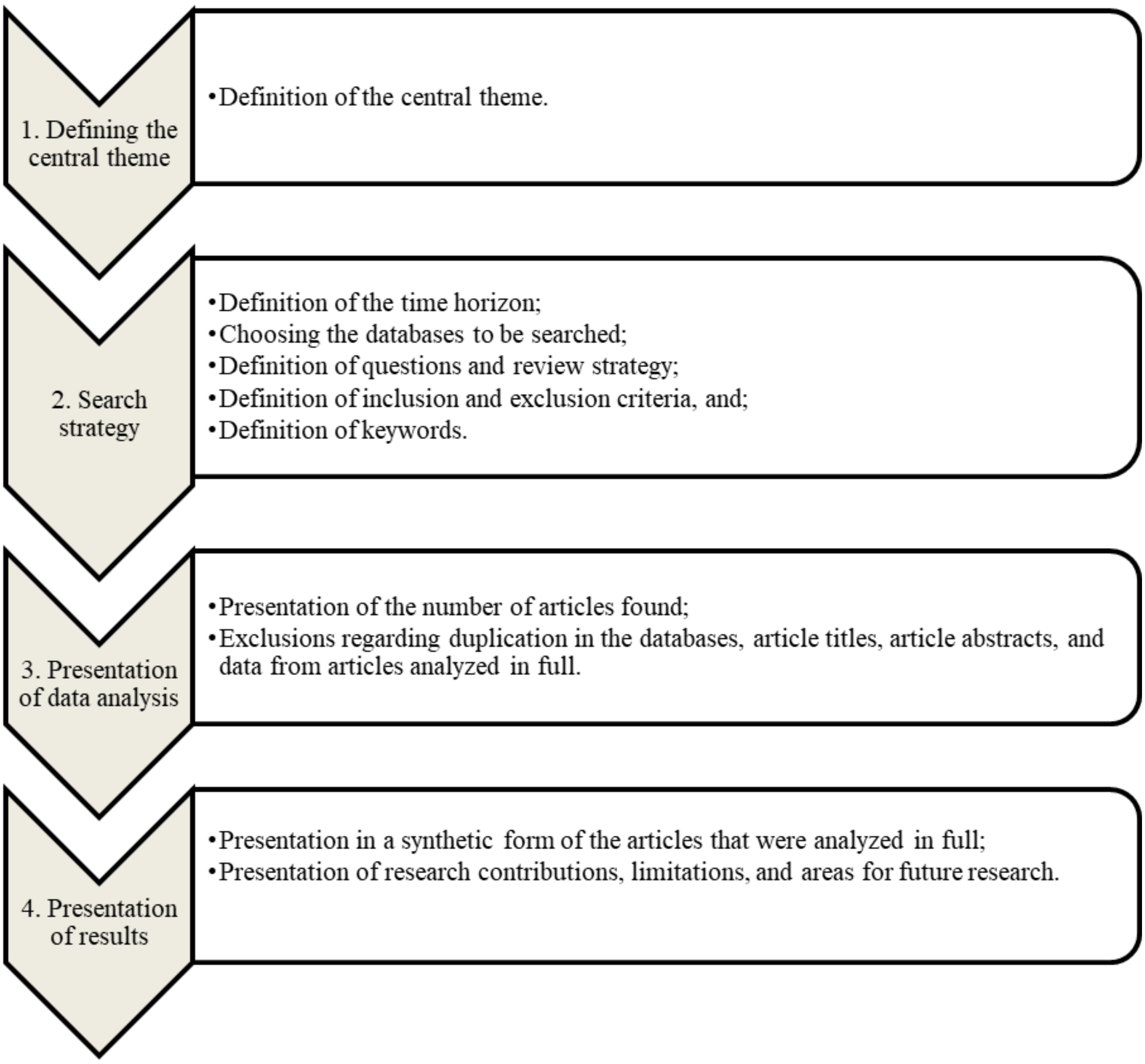

Figure 1 – Working method applied in conducting this research
Source: The authors.

In stage 2, the time horizon for the searches was first defined as 1960 to 2024, and the databases searched would be Scopus and the Web of Science (WOS) [36]–[38]. For this SLR, two review questions were developed: 1) What are the models and methods for measuring forklift efficiency? and 2) What are the objectives of these models and methods? What do they measure? Furthermore, we defined that the review strategy would be aggregative and defined the keywords for the search as well. These keywords were separated into three groups: (i) forklift: represented by the keywords lift truck, lifttruck, forklift, fork lift, forktruck, fork truck, truck lift, trucklift and fork hoist; (ii) measurement: measurement, assessment, mensuration, admeasurem, meterage, measure, appraisal, estimate, evaluation, valuation, appraisement, and; (iii) efficiency: efficiency, effectiveness, productivity, utility, utilization, capacity, and capability. Based on these definitions, a research protocol was developed (Figure 2).

Context: Understand how efficiency or utilization or productivity measurement is applied in forklift operation.
Time horizon: Between the years 1960 and 2024.
Languages: English.
Review question:
Question 1 – What are the models and methods applied to measure forklift efficiency?
Question 2 – What are the objectives of these models and methods? What do they measure?
Review strategy: Aggregative.
Search Criteria
Inclusion: Research that presents models and methods for measuring forklift efficiency.
Exclusion:
– Publications that do not present a defined area of study and that do not present details of these models, methods, and frameworks either applied or developed;
– Scientific publications that are not peer-reviewed;
– Publications other than articles published in scientific journals, periodicals, and conferences;
– Publications that are not available.
Database: Scopus and Web of Science (WOS).
Search terms in English: Search string
Scopus: (TITLE-ABS-KEY ((“lift truck” OR “lifttruck” OR “fork lift” OR “forklift” OR “forktruck” OR “fork truck” OR “truck lift” OR “trucklift” OR “fork hoist”) AND (“measurement” OR “assessment” OR “mensuration” OR “admeasurem” OR “meterage” OR “measure” OR “appraisal” OR “estimate” OR “evaluation” OR “valuation” OR “appraisement”) AND (“efficiency” OR “effectiveness” OR “productivity” OR “utility” OR “utilization” OR “capacity” OR “capability”)).
Web of Science:
(“lift truck” OR “lifttruck” OR “fork lift” OR “forklift” OR “forktruck” OR “fork truck” OR “truck lift” OR “trucklift” OR “fork hoist”) AND (“measurement” OR “assessment” OR “mensuration” OR “admeasurem” OR “meterage” OR “measure” OR “appraisal” OR “estimate” OR “evaluation” OR “valuation” OR “appraisement”) AND (“efficiency” OR “effectiveness” OR “productivity” OR “utility” OR “utilization” OR “capacity” OR “capability”) (Topic).

Figure 2 – Research protocol applied to this SLR
Source: The authors.

II. Result

After applying the research protocol in the Scopus and WOS databases to verify the number of scientific articles and journals published between 1960 and 2024, the results included articles published in scientific journals and peer-reviewed journals [38], [39] (Table 1).

Table no 1 Publications found in Scopus and Web of Science databases from 1960 to 2024

Keywords	Scopus	WOS
(“lift truck” OR “lifttruck” OR “fork lift” OR “forklift” OR “forktruck” OR “fork truck” OR “truck lift” OR “trucklift” OR “fork hoist”) AND (“measurement” OR “assessment” OR “mensuration” OR “admeasurem” OR “meterage” OR “measure” OR “appraisal” OR “estimate” OR “evaluation” OR “valuation” OR “appraisement”) AND (“efficiency” OR “effectiveness” OR “productivity” OR “utility” OR “ability” OR “capacity” OR “capability”).	274	85

Source: The authors.

Once the search in the databases was completed, the analysis of the results began, which was carried out through the following steps: a) identification and elimination of duplicate results in both research databases; b) reading of the titles; c) reading of the abstracts; d) search for the full publications and verification of availability; and e) reading the full publications for the publication of the results. Figure 3 shows the structure of the analysis carried out in the Scopus and Web of Science databases [40], [41].

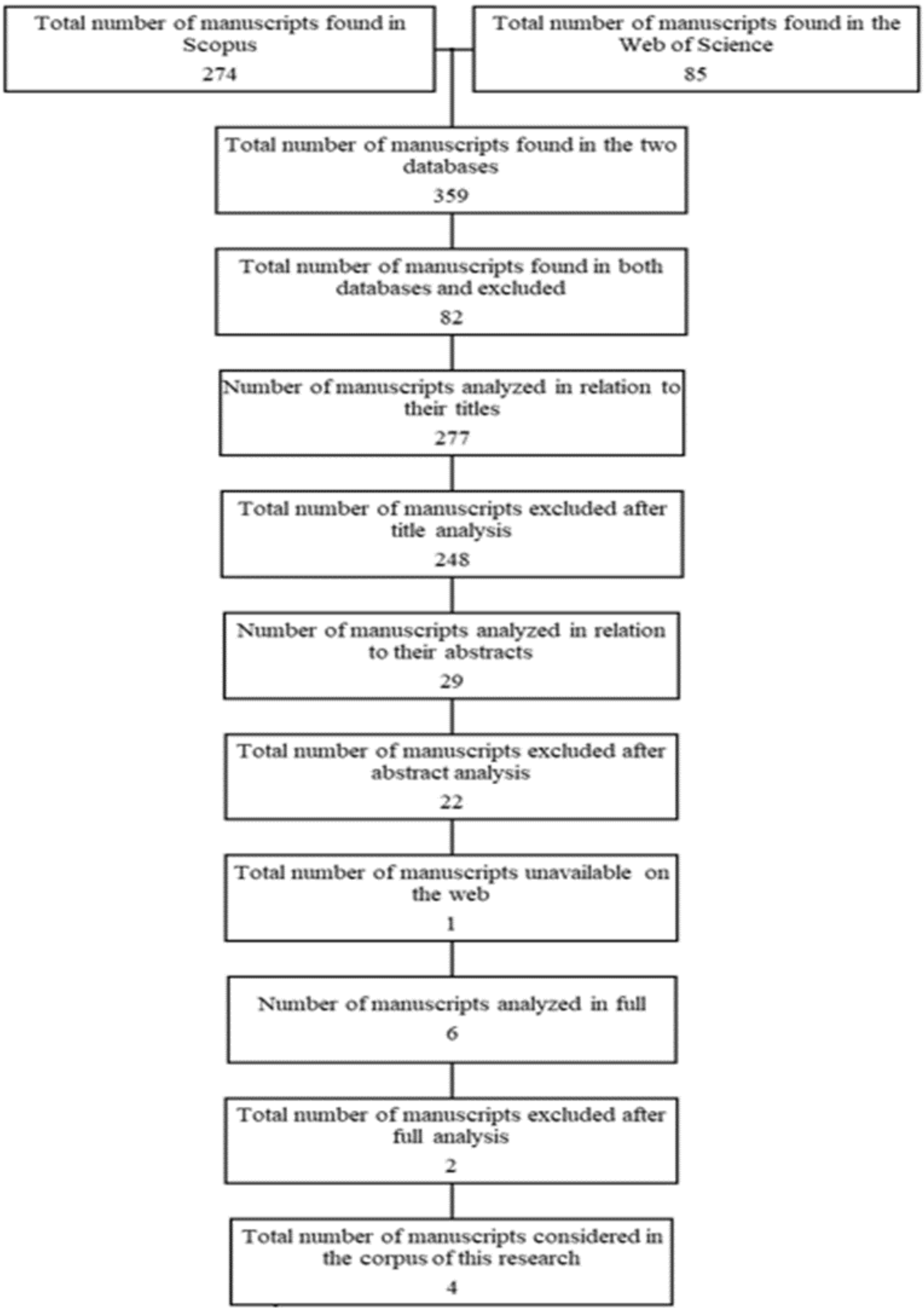

Figure 3 – Structure of the research analysis carried out in the Scopus and Web of Science databases
Source: The authors.

After analyzing the 359 articles found in these databases, 82 were excluded because they were published in both databases. Thus, 257 manuscripts were analyzed in relation to their title. After this analysis, 248 articles were excluded. Of the remaining 29, 22 were excluded after analyzing their abstract. Finally, seven files remained for complete analysis. Of these, the article entitled "Lift truck for in-process handling" by Jones RD, published in 1976 in the Technical Paper Society of Manufacturing Engineers was not found available on the web and was therefore excluded from the analysis. Based on the analyses and readings carried out on the publications found in the Scopus and Web of Science databases, only six of them were read in full. After reading these manuscripts in full, two works were excluded: (i) Antenna concepts for RFID on forklift trucks, published in the 2nd International Multi-Conference on Engineering and Technological Innovation, Proceedings (IMETI) in 2009 by Jungk A., Heiserich G. and Overmeyer L., and; (ii) Lidar positioning and path tracking of a single steering wheel automated guided vehicle forklift, published in 2024 by Yao M., Duan J., Shao Z., Yuan S., and Su Y. in the Journal of Tsinghua University. Finally, the four works that are part of the corpus of this research and their information are presented in Table 2.

Table no 2 Results found in the Scopus and WOS databases regarding the research topic in the period between 1960 and 2024

Id	Title	Author(s)	Institution	Publication	Keywords
1	Assignment-simulation model for forklifts in a distribution center with aisle constraints	Becerra-Fernandez M., Romero OR, Trujillo-Diaz J. and Herrera MM	School of Engineering, Science and Technology, Universidad del Rosario, Bogotá, Colombia; Fundación Universitaria Internacional de La Rioja - UNIR, Bogotá, Colombia; Faculty of Economic Science, Universidad Militar Nueva Granada, Bogotá, Colombia	Simulation Modeling Practice and Theory, (2024): 133, 102902.	Discrete-event simulation (DES); Forklift; Logistics; Resource allocation; Warehouse
2	A better indexing method for the closest open location policy in forklift warehouse operations	Nguyen DA, Pham TT and Nguyen VD	Ho Chi Minh City University of Technology - Vietnam	In: AETA 2018- Recent advances in electrical engineering and related sciences: theory and application. Springer International Publishing, (2020): 251–260.	Closest open location; COL; Storage location assignment problem; Warehouse management problem
3	FUCOM method in group decision-making: Selection of forklift in a warehouse	Fazlollahtabar H., Smailbašic A., and Stevic Ž.	Department of Industrial Engineering, School of Engineering, Damghan University, Damghan, Iran; University of East Sarajevo, Faculty of Transport and Traffic Engineering, Doboj, Bosnia and Herzegovina	Decision Making: Applications in Management and Engineering (2019), 2.1: 49-65.	Discrete-event simulation (DES); Forklift; Logistics; Resource allocation; Warehouse
4	Operations by forklifts in warehouses	Burinskiene A.	Vilnius Gediminas Technical University, Lithuania	European Modeling and Simulation Symposium. European Modeling and Simulation (2012).	Forklifts; Routing; Savings; simulation; Warehouse

Source: The authors.

After presenting the analysis of the data found in the databases, the summaries of the articles read in full are presented.

In step 4, after being read, the articles that make up the corpus of this research are presented synthetically. The first article to be presented is the work published in 2024 by Becerra-Fernandez et al.[42]. This article aimed to develop a discrete event simulation (DES) model to optimize the allocation of counterbalanced forklifts in a LDC with aisle restrictions. Focused on a consumer goods company, the model sought to improve the performance of logistics operations, considering operational costs and customer service levels, and addresses a gap in the existing literature when dealing with spatial restrictions in warehouses. The methodology adopted involved the collection of historical data from the warehouse management system used to feed the simulation model. The process included steps such as problem formulation, definition of hypotheses, conceptual modeling, data collection and validation, and execution of simulations in different scenarios.

The focus was on the analysis of three leading performance indicators: the pallet rate per hour (PHR), the percentage of pallets in the queue (PPQ), and the percentage of pallets stored (PPS). The results showed that the use of two counterbalanced forklifts significantly increased the average pallet dispatch rate per hour from 26 to 45 while reducing the percentage of pallets in the queue from 55% to 13%. However, the increase in the number of reach trucks did not have a significant impact on overall performance, but it did generate an increase in blockages due to aisle restrictions. The ideal scenario identified was the use of two counterbalanced forklifts and three reach trucks. The study concluded that counterbalanced forklifts are the main operational bottleneck, but the indiscriminate increase in the number of forklifts does not improve logistics performance due to the structural constraints of the LDC. The simulation revealed that the appropriate combination of equipment can increase operational efficiency and optimize the use of available resources without significant additional costs. As a contribution, the proposed model can be adapted to other distribution centers with similar characteristics. It also serves as a methodological guide for resource planning, reducing uncertainties and implementation costs. Future research should focus on the application of DES for strategic decisions in logistics, considering factors such as time and cost in complex operational environments.

The publication by Nguyen *et al*[43] proposed a time-based indexing method to optimize the closest open location (COL) policy in warehouse operations with forklifts. This method seeks to reduce the travel, loading, and unloading time of pallets, improving efficiency and reducing costs in storage and retrieval operations. The methodology involved the creation of an algorithm based on realistic assumptions for a frozen product warehouse, using a FIFO (first in, first out) policy. The simulated warehouse had a capacity for 480 storage locations, and the model considered variables such as travel distance, lifting time, and equipment speed. The simulations were performed in an integrated V-REP and MATLAB environment, allowing testing of different scenarios with time- and distance-based policies. The results showed that the time-based policy significantly reduced the total operation time compared to the distance-based approach, especially at warehouse fill levels between 60% and 80%. This policy also promoted a more even distribution of pallets on the shelves, increasing the stability of the structures and extending their useful life. The analysis of the operating time revealed that the reduction in loading time offset the additional travel time costs, resulting in savings of 4% to 8% in total time at normal operating levels. As the warehouse approaches full capacity, the performance gap between the methods diminishes, but the time-based approach still proves advantageous in less crowded environments. The study concluded that the time-based policy offers measurable operational benefits, including increased efficiency and cost savings. Future research should explore more complex scenarios and more extended periods to assess the additional impacts of this approach, with a focus on route planning and appropriate scheduling for improved logistics operations.

The study by Fazlollahtabar *et al*., 2019 [44], aimed to develop a decision support model to select the most suitable sideloader for a warehouse using a combination of the FUCOM (Full Consistency Method) and WASPAS (Weighted Aggregated Sum Product Assessment) methods. The main objective was to identify an efficient solution that met the established criteria and optimized the operational performance in the internal transport of the company Euro-Roal. The methodology applied was based on the definition of seven criteria for evaluating the forklifts: purchase price, age, working hours, maximum load capacity, maximum lifting height, ecological factors, and availability of spare parts. The determination of the relative weights of the criteria was performed using the FUCOM method, which ensures consistency in comparisons between criteria. Then, the WASPAS method was used to evaluate and rank ten side loader alternatives, combining the weighted sum and weighted product models. The results showed that the most relevant criteria were working hours and maximum load capacity, with weights of 0.409 and 0.133, respectively. The BAUMANN EHX 30/14/51 forklift was classified as the most suitable to meet the company’s needs, presenting the best overall performance among the alternatives evaluated. This solution was validated by a sensitivity analysis, which demonstrated stability in the results when applying different multicriteria decision methods. The developed model allowed an objective analysis of the parameters involved in the decision-making process, ensuring greater precision in the choice of the forklift. In addition, the application of the FUCOM method proved to be advantageous in reducing inconsistencies in comparisons and providing greater reliability in the weights attributed to the criteria. The research concluded that the integration of the FUCOM and WASPAS methods is an efficient approach to support decisions in complex contexts, such as the selection of logistics equipment. Future studies can explore the operational performance of the selected forklift in real scenarios and investigate the applicability of the model in different industrial sectors.

The study by Burinskiene [45]seeks to identify improvements in the logistics system by analyzing forklift operations in warehouses, with a focus on increasing productivity and reducing costs and operating times. It emphasizes the importance of these machines, which represent significant investments but have the potential to optimize logistics processes by reducing unproductive movements and building lower-cost routes. The methodology is divided into two main parts. In the first, simulation methods were applied to model and identify optimized routes for forklifts. The second part involved comparative and financial analyses to assess the impacts of the proposed improvements, considering scenarios of traditional use and with advanced technologies, such as radio frequency (RF) terminals. The results of the simulations showed that the use of forklifts equipped with RF terminals enabled a significant reduction in travel time, ranging from 27% to 37%, which was attributed to the elimination of the need to return to a central warehouse to obtain new instructions, allowing tasks to be distributed in real-time. In financial terms, the proposed improvements resulted in a total cost reduction of approximately 9% over five years, which was achieved by reducing operating costs, such as operating time and machine wear. In addition, the study indicated that the implementation of infrastructure associated with RF terminals presents a significant return on investment. The research concluded that the application of optimized routes and technologies such as RF terminals is essential to maximize warehouse efficiency. The reduction in costs and operating times reinforces the viability of these improvements, which can be expanded by increasing the number of forklifts in operation, further increasing productivity and logistics competitiveness.

III. Discussion

The systematic review showed a significant gap in the literature on measuring forklift efficiency. Most of the studies analyzed are limited to simple indicators, such as hours worked or utilization rate, often monitored by hour meters. This approach does not consider more complex metrics, such as productivity, sustainability, or environmental impact, which are essential for efficient management in dynamic logistics environments. Although some studies use multicriteria methods for forklift selection, such as FUCOM and WASPAS, these models do not fully address the operational dynamics in warehouses and distribution centers. Aspects such as loading times, route optimization, and unplanned stops are neglected, which limits the practical applicability of the methods to improve overall efficiency[44], [45].

This lack of consolidated models can be attributed to the complexity of logistics operations, which vary across sectors and contexts. Many studies prioritize easily measurable indicators, ignoring the specificities of each operation, which demonstrates the need for adaptable frameworks that integrate contextual variables and provide a holistic view of forklift performance [42], [43]. Another critical aspect is the disconnect between emerging technological demands and measurement methodologies. Technologies such as IoT, real-time sensors, and artificial intelligence have the potential to transform logistics management, but little has been explored in the literature as tools for measuring forklift efficiency. The integration of these technologies can provide real-time insights, enabling faster and more accurate operational adjustments. Existing studies also lack robust, practical applications. Although methodologies such as discrete-event simulations are promising, they are still restricted to theoretical or experimental scenarios, which limits their large-scale adoption by logistics companies. There is, therefore, a vast field for research to validate these approaches in authentic and diverse contexts [9], [16].

Furthermore, an excessive focus on economic indicators can obscure other crucial factors, such as environmental impact and workplace safety. Future models must balance financial priorities with sustainability and well-being issues, considering trends such as green logistics and corporate social responsibility. The development of integrated models, which combine advanced technologies with comprehensive metrics, is crucial to fill this gap. Such models and/or frameworks would not only improve operational efficiency but also strengthen the competitiveness of logistics companies, responding to the demands of an increasingly demanding technological market.

To guide studies on this topic, in line with trends in efficiency analysis, it is necessary to develop research that presents models and methods for measuring operational efficiency for forklifts, given that these assets are the leading equipment for moving materials in Logistics Distribution Centers. Furthermore, it is necessary to develop smart devices, based on the concepts of the Internet of Things (IoT) for data collection in order to not depend on notes made by drivers, since in addition to harming the productivity of these operations, they impact the efficiency of the equipment due to the accuracy of the information that depends on human beings.

IV. Conclusion

The study sought to explore models and methods used to measure the efficiency of forklifts in logistics operations. Based on a Systematic Literature Review (SLR), the research identified gaps, highlighting the absence of a consolidated model to measure the efficiency of this equipment, with the frequent use of hour meters to monitor hours worked.

Few comprehensive studies on forklift efficiency were found, demonstrating that current measurement is limited to fundamental indicators such as the utilization rate through hours worked by the equipment, pallet rate per hour, percentage of pallets in the queue, and percentage of pallets stored. In addition, the importance of more robust models that consider aspects such as productivity and capacity was highlighted, expanding the view on efficiency beyond traditional use. This research aims to contribute by offering a detailed overview of existing approaches. In addition, it presents the FUCOM and WASPAS methodologies addressed in the analyzed studies, exemplifying how the integration of multicriteria methods can improve the assessment of operational efficiency.

This study sought to fill a gap in the literature by synthesizing disparate knowledge and highlighting the need for models that integrate efficiency measurements beyond simple hours worked or utilization rates. This research has direct applicability to distribution centers and logistics warehouses, offering insights for managers seeking to optimize logistics processes and justify investments in more advanced technologies. The inclusion of new metrics and frameworks can guide the implementation of solutions such as smart forklifts and routing systems based on artificial intelligence, increasing the impact on logistics performance.

The analysis was limited by the scarcity of robust publications in the field, with only six studies considered relevant to compose the final corpus. The search covered articles up to 2024 and may not reflect the most recent innovations or specific regional approaches outside the context analyzed. The lack of studies that address practical integration and concrete results may limit the immediate applicability of the reviewed frameworks.

Suggestions for future studies include the development of models that integrate contextual variables, such as loading time, equipment downtime, optimized operations, and environmental impacts. Technologies such as IoT, artificial intelligence, and real-time sensors should also be explored to measure forklift efficiency, as well as investigate models that measure logistics performance in real scenarios, considering different industrial sectors and specific operating characteristics.

References

[1] Q. Zhao, X. Zhang, And P. Wang, "Multi-Type Equipment Selection And Quantity Decision Optimization In Intelligent Warehouse," Ieee Access, Vol. 12, No. April, Pp. 63515–63527, 2024, Doi: 10.1109/Access.2024.3395288.

[2] B. Nadondu, A. Chanpahol, S. Srisawad, And S. Thiakthum, "Improving Forklift Efficiency By Ecrs Techniques: A Case Study In A Logistics Company," Evergreen, Vol. 11, No. 1, Pp. 306–313, 2024, Doi: 10.5109/7172286.

[3] A. Jungk, G. Heiserich, And L. Overmeyer, "Antenna Concepts For Rfid On Forklift Trucks," Imeti 2009 - 2nd Int. Multi-Conference Eng. Technol. Innov. Proc., Vol. 1, Pp. 112–116, 2009, [Online]. Available: Https://Www.Scopus.Com/Inward/Record.Uri?Eid=2-S2.0-84898468175&Partnerid=40&Md5=57140cc3ba546e1bcd62dd96e0a9c3fc

[4] R. L. Unger And T. G. Bobick, "Bureau Of Mines Research Into Reducing Materials-Handling Injuries.," Us Bur Of Mines, Pittsburgh, Pa, Usa, Us Bur Of Mines, Pittsburgh, Pa, Usa, 1986. [Online]. Available: Https://Www.Scopus.Com/Inward/Record.Uri?Eid=2-S2.0-0022915518&Partnerid=40&Md5=B7bc23406f15beb6da8962a50e7af4ea

[5] N. Chen, Q. Liu, Ž. Stević, M. Andrejić, And V. Pajić, "An Integrated Cost Based Approach For Warehouse Performance Evaluation: A New Multiphase Model," Alexandria Eng. J., Vol. 101, No. April, Pp. 62–77, 2024, Doi: 10.1016/J.Aej.2024.05.063.

[6] N. Vodichev Et Al., "Real-Time Distance Estimation Algorithm For Objects In Warehouse Based On Monocular Camera Data For An Autonomous Unmanned Forklift," Eur. Phys. J. Spec. Top., Vol. 123, 2025, Doi: 10.1140/Epjs/S11734-024-01452-4.

[7] N. S. F. Abdul Rahman, N. H. Karim, R. Md Hanafiah, S. Abdul Hamid, And A. Mohammed, "Decision Analysis Of Warehouse Productivity Performance Indicators To Enhance Logistics Operational Efficiency," Int. J. Product. Perform. Manag., Vol. 72, No. 4, Pp. 962–985, 2023, Doi: 10.1108/Ijppm-06-2021-0373.

[8] K. Aravindaraj, P. R. Chinna, M. Kalidhasan, And K. Srinivasan, "A Contemporary On Indian Government Initiatives And Challenges Of Warehouse Industry," Int. J. Recent Technol. Eng., Vol. 8, No. 2 Special Issue 6, Pp. 741–744, 2019, Doi: 10.35940/Ijrte.B1139.0782s619.

[9] F. Nunes, "Application Of Structural Equation Modeling For Evaluation Of Forklift Management Model : An Analysis In Brazilian Warehouses," J. Enginineering Technol. Manag. - Jet-M, Vol. 74, No. 4, Pp. 443–466, 2024.

[10] M. Tutam And R. De Koster, "To Walk Or Not To Walk? Designing Intelligent Order Picking Warehouses With Collaborative Robots," Transp. Res. Part E Logist. Transp. Rev., Vol. 190, No. July, P. 103696, 2024, Doi: 10.1016/J.Tre.2024.103696.

[11] B. Song, W. Y. Wang, And Z. Sun, "The Research Of Warehouse Automation System Based On Zigbee & Rfid," Applied Mechanics And Materials, Vol. 416–417. College Of Information Science And Technology, Qingdao University Of Science And Technology, 266061 Qingdao, China, Pp. 753–756, 2013. Doi: 10.4028/Www.Scientific.Net/Amm.416-417.753.

[12] A. Radaev And V. Leventsov, "The Methodology For Substantiating The Materials Handling Equipment Of A Unit Load Warehousing System," Int. J. Qual. Res., Vol. 12, No. 4, Pp. 989–1016, 2018, Doi: 10.18421/Ijqr12.04-13.

[13] D. Shishebori And S. Dehnavi-Arani, "A Multi-Stage Stochastic Programming Approach In A Dynamic Cell Formation Problem With Uncertain Demand: A Case Study," Int. J. Supply Oper. Manag., Vol. 6, No. 1, Pp. 67–87, 2019, Doi: 10.22034/2019.1.6.

[14] N. Boysen, D. Briskorn, And S. Emde, "Parts-To-Picker Based Order Processing In A Rack-Moving Mobile Robots Environment," Eur. J. Oper. Res., Vol. 262, No. 2, Pp. 550–562, 2017, Doi: 10.1016/J.Ejor.2017.03.053.

[15] R. Manzini, R. Accorsi, M. Gamberi, And S. Penazzi, "Modeling Class-Based Storage Assignment Over Life Cycle Picking Patterns," Int. J. Prod. Econ., Vol. 170, Pp. 790–800, 2015, Doi: 10.1016/J.Ijpe.2015.06.026.

[16] A. Kamali, "Iot ' S Potential To Measure Performance Of Mhe In Warehousing," Ciit Int. J. Data Min. Knowl. Eng., Vol. 6, No. August, Pp. 93–99, 2019.

[17] A. Abideen And F. B. Mohamad, "Improving The Performance Of A Malaysian Pharmaceutical Warehouse Supply Chain By Integrating Value Stream Mapping And Discrete Event Simulation," J. Model. Manag., Vol. 16, No. 1, Pp. 70–102, 2020, Doi: 10.1108/Jm2-07-2019-0159.

[18] F. Halawa, H. Dauod, I. G. Lee, Y. Li, S. W. Yoon, And S. H. Chung, "Introduction Of A Real Time Location System To Enhance The Warehouse Safety And Operational Efficiency," Int. J. Prod. Econ., Vol. 224, No. October 2019, P. 107541, Jun. 2020, Doi: 10.1016/J.Ijpe.2019.107541.

[19] B. Emde, J.-F. Höfinghoff, And L. Overmeyer, "Evaluation Of Rfid Equipment Using Performance Figures ," Logist. J., Vol. 2012, Pp. 1–8, 2012, Doi: 10.2195/Lj_Notrev_Emde_De_201204_01.

[20] H. Klaus And J. Van Den Brand, "How Lift Truck Innovation Can Improve Your Bottom-Line," In Aistech - Iron And Steel Technology Conference Proceedings, 2014, Vol. 3, Pp. 3829–3836. [Online]. Available: Https://Www.Scopus.Com/Inward/Record.Uri?Eid=2-S2.0-84905843153&Partnerid=40&Md5=33071e4b09d087f3787b946f9d6c6da8

[21] B. Zou, X. Xu, Y. Gong, And R. De Koster, "Modeling Parallel Movement Of Lifts And Vehicles In Tier-Captive Vehicle-Based Warehousing Systems," Eur. J. Oper. Res., Vol. 254, No. 1, Pp. 51–67, 2016, Doi: 10.1016/J.Ejor.2016.03.039.

[22] A. Burinskiene, "The Travelling Of Forklifts In Warehouses," Int. J. Simul. Model., Vol. 10, No. 4, Pp. 204–212, 2011, Doi: 10.2507/Ijsimm10(4)4.191.

[23] J. Bidot, L. Karlsson, F. Lagriffoul, And A. Saffiotti, "Geometric Backtracking For Combined Task And Motion Planning In Robotic Systems," Artif. Intell., Vol. 247, Pp. 229–265, 2017, Doi: 10.1016/J.Artint.2015.03.005.

[24] A. P. Murdan And M. Z. A. Emambocus, "Indoor Positioning System Simulation For A Robot Using Radio Frequency Identification," In Proceedings Of The 13th Ieee Conference On Industrial Electronics And Applications, Iciea 2018, 2018, Pp. 986–991. Doi: 10.1109/Iciea.2018.8397855.

[25] M. Subramaniyam, S. Park, S.-I. Choi, J.-Y. Song, And J. K. Park, "Efficiency Evaluation Of Micro Factory For Micro Pump Manufacture," J. Mech. Sci. Technol., Vol. 23, No. 2, Pp. 498–503, 2009, Doi: 10.1007/S12206-008-1101-6.

[26] A. Taliaferro And C.-A. Guenette, "Industry 4.0 And Distribution Centers A Deloitte Series On Digital Manufacturing Enterprises," Deloitte. Univ. Press, Vol. I, No. 1, Pp. 2–9, 2016, [Online]. Available: Https://Dupress.Deloitte.Com/Content/Dam/Dup-Us-En/Articles/3294_Industry-4-0-Distribution-Centers/Dup_Industry-4-0-Distribution-Centers.Pdf

[27] H. Iben, H. Baumann, C. Ruthenbeck, And T. Klug, "Visual Based Picking Supported By Context Awareness: Comparing Picking Performance Using Paper-Based Lists Versus Lists Presented On A Head Mounted Display With Contextual Support," In Icmi-Mlmi'09 - Proceedings Of The International Conference On Multimodal Interfaces And The Workshop On Machine Learning For Multimodal Interfaces, 2009, Pp. 281–288. Doi: 10.1145/1647314.1647374.

[28] F. Nurprihatin, Elvina, G. D. Rembulan, K. Christianto, And H. Hartono, "Decision Support System For Truck Scheduling In Logistic Network Through Cross-Docking Strategy," Iop Conf. Ser. Earth Environ. Sci., Vol. 1811, No. 1, Pp. 0–10, 2021, Doi: 10.1088/1742-6596/1811/1/012009.
[29] P. C. Pwc, "Five Forces Transforming Transport & Logistics - Pwc Cee Transport & Logistics Trend Book 2019," P. 40, 2019, [Online]. Available: Https://Www.Pwc.Pl/Pl/Pdf/Publikacje/2018/Transport-Logistics-Trendbook-2019-En.Pdf
[30] J. S. Park, S. J. Lee, J. Jimenez, S. K. Kim, And J. W. Kim, "Indoor Positioning-Based Mobile Resource Movement Data Management System For Smart Factory Operations Management," Int. J. Distrib. Sens. Networks, Vol. 16, No. 3, 2020, Doi: 10.1177/1550147720909760.
[31] M. I. W. M. Morandi And L. F. R. Camargo, "Systematic Literature Review," In Design Science Research: A Method For Science And Technology Advancement, Switzerland: Springer International Publishing, 2015, P. 176. Doi: 10.1007/978-3-319-07374-3.
[32] E. H. Grosse, C. H. Glock, M. Y. Jaber, And W. P. Neumann, "Incorporating Human Factors In Order Picking Planning Models: Framework And Research Opportunities," Int. J. Prod. Res., Vol. 53, No. 3, Pp. 695–717, Feb. 2015, Doi: 10.1080/00207543.2014.919424.
[33] P. Anggradewi, Aurelia, S. Sardjananto, And A. D. Ekawati, "Improving Quality In Service Management Through Critical Key Performance Indicators In Maintenance Process: A Systematic Literature Review," Qual. - Access To Success, Vol. 20, No. 173, Pp. 72–79, Dec. 2019, Accessed: Apr. 09, 2020. [Online]. Available: Https://Www.Scopus.Com/Inward/Record.Uri?Eid=2-S2.0-85076557097&Partnerid=40&Md5=9e0adc4acad7dfbc869e4892652343bd
[34] A. Al-Shaebi, N. Khader, H. Daoud, J. Weiss, And S. W. Yoon, "The Effect Of Forklift Driver Behavior On Energy Consumption And Productivity," Procedia Manuf., Vol. 11, Pp. 778–786, 2017, Doi: 10.1016/J.Promfg.2017.07.179.
[35] L. S. Goecks, M. De Souza, T. P. Librelato, And L. R. Trento, "Design Science Research In Practice: Review Of Applications In Industrial Engineering," Gest. E Prod., Vol. 28, No. 4, 2021, Doi: 10.1590/1806-9649-2021v28e5811.
[36] F. Nunes, L. L. P. Chiká, And C. Santos, "Mif: A Mapping Approach Based On The Combination Of Vsm 4.0 And Shingo Production Engine Applied In A Case Study Of Brazilian Logistics Distribution Centre," Int. J. Process Manag. Benchmarking, Vol. 18, No. 2, Pp. 183–215, 2024, Doi: 10.1504/Ijpmb.2024.141536.
[37] T. Strassburguer, F. De Lima Nunes, A. Peixoto Possebon, J. A. V. Antunes, And C. H. Nodari, "Lean Office: Proposition And Application Of A Process-Mapping Method Based On The Shingo Production Mechanism (Spm)," Emj - Eng. Manag. J., Vol. 34, No. 4, Pp. 1–20, 2023, Doi: 10.1080/10429247.2023.2286881.
[38] F. Nunes, G. L. R. G. L. R. Vaccaro, J. A. V. Antunes Júnior, And J. A. V. Antunes, "The Development Of The Hyundai Production System: The Historical Evolution," J. Manuf. Syst., Vol. 43, No. Part 1, Pp. 47–57, 2017, Doi: 10.1016/J.Jmsy.2017.02.003.
[39] K. M. Finn, F. D. L. Nunes, C. H. Nodari, And J. D. Sordi, "Service Level Agreement Directed To Suppliers Of Materials And Services Of The Petrochemical Sector: A Criteria Analysis," Rev. Ibero-Americana Estratégia, Vol. 19, No. 4, Pp. 151–171, 2020, Doi: 10.5585/Riae.V19i4.16847.
[40] F. Nunes, "Proposição De Modelo Para A Medição De Eficiência Produtiva Dos Ativos De Carga E Descarga Do Modal Rodoviário Em Terminais E Bases De Distribuição De Combustíveis. Phd Thesis.," Universidade Do Vale Do Rio Dos Sinos - Unisinos, 2024.
[41] F. Nunes, "Olue - Overall Load And Unload Stations Effectiveness : A Model For Measuring The Efficiency In Bulk Liquid Storage Terminals (In Press)," Int. Product. Qual. Manag., P. 40, Doi: 10.1504/Ijpqm.2023.10060852.
[42] M. Becerra-Fernandez, O. R. Romero, J. Trujillo-Diaz, And M. M. Herrera, "Assignment-Simulation Model For Forklifts In A Distribution Center With Aisle Constraints," Simul. Model. Pract. Theory, Vol. 133, No. July 2023, P. 102902, 2024, Doi: 10.1016/J.Simpat.2024.102902.
[43] D. A. Nguyen, T. T. Pham, And V. D. Nguyen, "A Better Indexing Method For Closest Open Location Policy In Forklift Warehouse Operation," In Aeta 2018 - Recent Advances In Electrical Engineering And Related Sciences: Theory And Application, Vol. 554, Ho Chi Minh City University Of Technology, Ho Chi Minh City, Viet Nam, 2020, Pp. 251–260. Doi: 10.1007/978-3-030-14907-9_25.
[44] H. Fazlollahtabar, A. Smailbašic, And Ž. Stevic, "Fucom Method In Group Decision-Making: Selection Of Forklift In A Warehouse," Decis. Mak. Appl. Manag. Eng., Vol. 2, No. 1, Pp. 49–65, 2019, Doi: 10.31181/Dmame1901065f.
[45] A. Burinskiene, "Operations By Forklifts In Warehouses," In 24th European Modeling And Simulation Symposium, Emss 2012, 2012, Pp. 402–407. [Online]. Available: Https://Www.Scopus.Com/Inward/Record.Uri?Eid=2-S2.0-84871482635&Partnerid=40&Md5=B1269784a451c67bf3d9958cd3d3b7f7