Journal of Optimization in Industrial Engineering
Vol. 16, Issue 2, Summer & Autumn 2023, 147-155
DOI: 10.22094/JOIE.2023.1986710.2070

Research Article

Storage Zone Functions Optimization in Warehouses: A Systematic Review of Class-Based Storage

Nur Iftitah [a], Qurtubi Qurtubi [b,*], Muchamad Sugarindra [c]

[a,b,c] *Department of Industrial Engineering, Faculty of Industrial Technology, Universitas Islam Indonesia, Yogyakarta 55584, Indonesia*

Received 21 May 2023; Revised 20 August 2023; Accepted 27 August 2023

Abstract

In the global supply chain, warehouses play a significant role, yet the construction land for warehouse areas is decreasing. This issue requires the company to discover a method of optimizing the available warehouse area under various policies. This article contains a systematic review of class-based storage articles that becomes essential due to the absence of the latest and comprehensive similar literature. This study aims to analyze various policies for optimizing warehouse functions and provide direction for opportunities for future research in sustainable topics. A systematic review is employed in this study to search for articles from 2004-2023 originating from four journal databases, which are ScienceDirect, Emerald, tnfonline, and Researchgate; to be later organized based on the procedures of systematic literature review (SLR). The research results show various aspects, such as the purpose of conducting the research, the findings in the article, the impact of the results influencing the optimization of warehouse functions, and the gaps in previous studies, which are opportunities for future research to create more complex and comprehensive research results on similar research topics. It is expected that this study could contribute to filling in the theoretical gap by completing the existing literature. Therefore, scientific value can be added by presenting the newest comprehensive literature review.

Keywords: Class-based storage; Logistics; Optimization; Systematic review; Warehouse.

1. Introduction

In the global supply chain, warehouses play a crucial role (Eder, 2022). Unfortunately, warehouse land is scarce in many parts of Europe, Asia, and the United States, particularly in areas with major customer concentrations. The shortage of land has driven many companies to look for more compact storage systems (Xu, Zhao, Zou, & Li, 2019). One of the many decisions a warehouse manager faces is the layout design, which is critical. The layout has an influence on the overall efficiency and effectiveness of the warehouse and in turn the supply chain (Venkitasubramony & Adil, 2019). Many factors affect storage assignment. For example, order-taking methods, storage system sizes and layouts, material handling systems, product characteristics, demand trends, turnover rates, and space requirements (Chan & Chan, 2011).

One of the problems identified in the company lies in the raw material warehouse. The placement of raw materials is irregular, has not been placed according to the class of type of raw material, and has not implemented the FIFO (First in First Out) system when picking raw materials at the warehouse. So that operators often have difficulty finding the required raw materials and take more time than has been prepared to move raw materials from that place. This causes the production process in the company to be not optimal (Fitri, Moengin, & Puspitasari, 2023). Warehouse storage planning involves determining storage policies, space requirements, and specific locations within the warehouse for each product. One of them is class-based storage or storage grouped based on their respective classes (Muppani & Adil, 2008).

The company must carry out the system application that is oriented to optimizing the warehouse function must be carried out by the company. The basis of any warehouse strategy and design is cost minimization while achieving the desired level of customer service (Schenone, Mangano, Grimaldi, & Caglian, 2020). The next thing that can be applied in optimizing the warehouse function is the design of a good storage layout for the warehouse, which is expected to provide an optimal impact on going activities. The layout has an impact on corporate image, consumer relationships, capacity in the warehouse, ongoing processes, costs incurred, warehouse flexibility, and the quality of the work environment (Alfarokhi, Qurtubi, & Miranda, 2019). The efficiency of the order picking process (the average distance of the picking route) highly depends on the storage policy used, i.e., where the products are placed in the warehouse. The more structured a warehouse storage, the lower the costs and the higher speed of order pick-up (Le-Duc & De Koster, 2005). Later, these estimations are used for storage zone optimization.

2. Literature Review

The research discussed about class-based storage have been studied far before 2000, among others, the research by Guenov & Raeside (1992) that deliberated the influence of zone's profile in CBS storage on the process of S/R machine taking, while using; as AS/RS on CBS cannot be implemented to carousel system, Ha & Hwang (1994)

*Corresponding author Email address: qurtubi@uii.ac.id

studied the storage policy of throughput carousel system performance on machine, when storing/taking/emptying is progressing; at the same year Hwang & Ha (1994) also optimized class-based storage policy in carousel system to improve the system's throughput; in the following year, Kouvelis & Papanicolaou (1995) suggested the optimal studies for AS/RS referred to various class-based storage policies; in addition to that Sarker et al. (1994) tried to reduce the average transaction time per lane by incorporating dual-shuttle ideas to enhance the throughput system; while, Larson et al. (1997) maximized the utilization of floor space to provide solution on static issues, using class-based storage method.

Those empirical studies are still running now, yet, based on the search using software Publish or Perish (Harzing, 2007) on Scopus-indexed class-based storage, only one international proceeding article was found that provided the literature review on class-based storage location assignment (CBSLAP) (Bahrami, Piri, & Aghezzaf, 2019). Therefore, to accommodate a more complete and comprehensive insight, this discussion becomes crucial to answer the question of what result will be revealed in a systematic review of class-based storage topics.

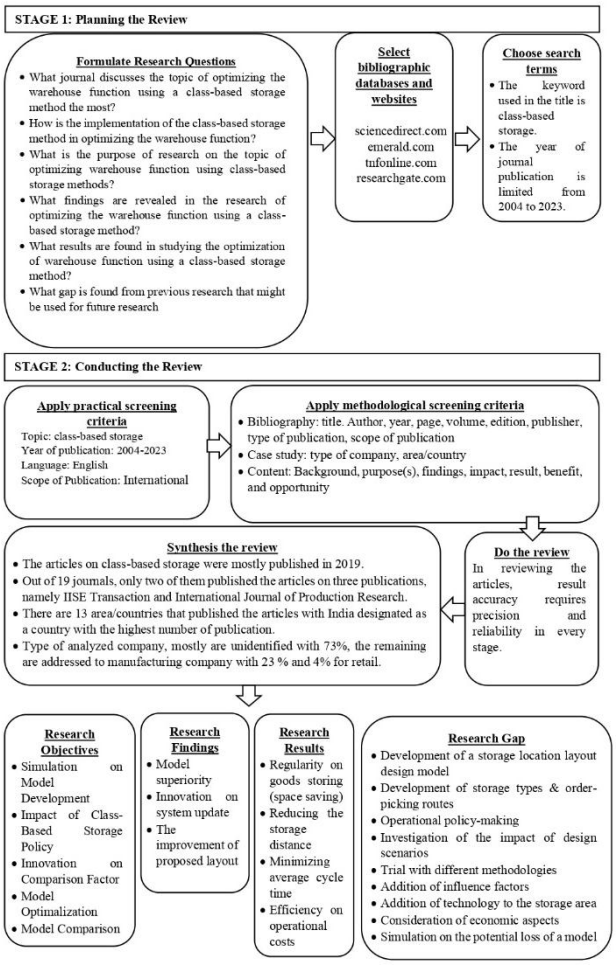

Fig. 1. Systematic literature review (slr) procedure. adopted: (Suhariyanto, 2019)

3. Methodology

The systematic review is employed for methodology. This method identifies, assesses, and interprets all findings on a topic to answer previous research questions. There are 26 articles relevant to the subject matter, namely warehouse optimization. The application of this method is Step two is the determination of the source (digital library) from the article search. And the third is reporting that involves the results of analysis and synthesis found from previous studies (research gap) and will become the research implications on the systematic reviews results, addressed for further research. Figure 1. demonstrates the systematic literature review (SLR) procedure that has been performed.

3.1. Planning the review

The first step is the Research Question (RQ), which is the initial and basic section of the SLR implementation. RQ is applied to guide the process of searching and extracting articles. In this study, 32 articles were obtained from various reference journal sources, including sciencedirect.com with six articles, emerald.com with two articles, tnfonline.com with nine articles, and researchgate.com with ten articles. Yet, six articles were published before 2000. Therefore, for novelty reasons, they were excluded. Thus, only 26 articles were reviewed. In searching for suitable articles that fit the topic of discussion, certain keywords are used, namely class-based storage.

3.2 Conducting (apply screening criteria)

The next step is the selection of all the articles that have been obtained with predetermined criteria. These criteria are the year of publication, the type of publication, and the scope of the publication. In this study, the year of publication used is within the range of 2004-2023. The overall publication type is in the form of articles. The scope of the publication is specified as international, with the use of foreign languages. In which, English dominates the article, so the results and impact of warehouse optimization research are obtained from various global perspectives.

3.3 Reporting (analyze the review)

The last step is to analyze the literature review that has been obtained earlier by using the review protocol. The purpose of using the method review protocol is to provide a thorough and up-to-date information overview of the research in the reviewed articles. The utilization of the review protocol is divided into three parts; the first bibliography consists of title, author, year, page, volume, edition, publisher, type of publication, and scope of publication. Table 1 shows a list of reviewed articles containing information on the research title, year of publication, publisher journal, and the method or approach used.

Table 1
List of Reviewed Articles

No.	Title	Year	Journal	Method or Approach
1	Improving order-picking performance through the implementation of class-based storage	2004	International Journal of Physical Distribution & Logistics Management	Class-based storage
2	Travel distance estimation and storage zone optimization in a 2-block class-based storage strategy warehouse	2005	International Journal of Production Research	Class-based storage
3	Design of class-based storage racks for minimizing travel time in a three-dimensional storage system	2007	International Journal of Production Research	Cubic-in-time for class-based storage
4	Design of a class-based storage picker to product order picking system	2007	International Journal Advanced Manufacture Technology	Class-based storage
5	A branch and bound algorithm for class-based storage location assignment	2008	European Journal of Operational Research	Class-based storage
6	Class-based storage-location assignment to minimize pick travel distance	2008	International Journal of Logistics: Research and Applications	Class-based storage
7	Optimal zone boundaries for two-class-based compact three-dimensional automated storage and retrieval systems	2009	IISE Transaction	Two-class-based storage
8	Improving the productivity of order picking of a manual pick and multi-level rack distribution warehouse through the implementation of class-based storage	2011	Expert systems with applications	Class-based storage
9	Optimal placement of warehouse cross-aisles in a picker-to-part warehouse with class-based storage	2012	IISE Transaction	Class-based storage
10	Class-based storage with exact S-shaped traversal routeing in low-level picker-to-part systems	2013	International Journal of Production Research	The dual-shuttle class-based storage
11	A travel time estimation model for a high-level picker-to-part system with class-based storage policies	2014	European Journal of Operational Research	Class-based storage
12	Class-based storage assignment in a unit-load warehouse employing AS/RS with inventory space allocation considering product specific setup to holding cost ratio	2014	Asia-Pacific Journal of Operational Research	Class-based storage
13	Warehouse design under class-based storage policy of shuttle-based storage and retrieval system	2015	IFAC (International Federation of Automatic Control)	Class-based storage
14	Modeling class-based storage assignment over life cycle picking patterns	2015	International Journal of Production Economics	Class-based storage
15	Comparative study between continuous models and discrete models for single cycle time of a multi-aisles automated storage and retrieval system with class based storage	2016	IFAC (International Federation of Automatic Control)	Class-based storage
16	Optimal two-class-based storage in a live-cube compact storage system	2017	IISE Transaction	Two-class-based storage
17	Optimal dimensions for multi-deep storage systems under class-based storage policies	2019	Cluster Computing	Multi-deep storage systems under class-based storage
18	An integrated design approach for class-based block stacked warehouse	2019	Facilities	Class-based storage
19	Improvement of storage system upright piano cabinet using class based storage	2019	IOP Conference Series: Materials Science and Engineering	Class-based storage
20	Class-based storage location assignment – an overview of the literature	2019	International Conference on Informatics in Control, Automation and Robotics	Class-based storage
21	An approach for computing AS/R systems travel times in a class-based storage configuration	2020	Production & Manufacturing Research	Class-based storage
22	Suggestion of raw material warehouse layout improvement using class-based storage method (case study of PT. XYZ)	2020	IOP Conference Series: Materials Science and Engineering	Class-based storage
23	An analytical approach for a performance calculation of shuttle-based storage and retrieval systems with multiple-deep and class-based storage	2022	Production & Manufacturing Research	Multiple-deep and class-based storage

No.	Title	Year	Journal	Method or Approach
24	Stochastic models of routing strategies under the class-based storage policy in fshbone layout warehouses	2022	Scientific Report	Fishbone layout warehouses under class-based storage
25	Raw material warehouse layout design using class-based storage method with ProModel and FlexSim simulation at automotive assembling company	2022	IEOM Society International	Class-based storage and validated using ProModel and FlexSim
26	Simulation model design and improvement of raw material warehouse layout with class-based storage method: A case study.	2023	International Journal of Advanced Engineering and Management Research	Class-Based Storage

The second is a case study consisting of company type and area/country. The publication of content is the last part which covers the background of the problem, objectives, description/findings, research impact, research results, research strengths, and research opportunities. After all the steps are accomplished, the results obtained will be applied as an analysis to answer questions from research questions and as a discovery for future research opportunities. Table 2. illustrates an overview review protocol used in this research. Review protocol determines the method that will be involved to tailor a certain systematic review. The pre-determined protocol is required to decrease the possibility of the author's bias (Suhariyanto, Wahab, & Rahman, 2017).

Table 2
Protocol Review

	Bibliography
Title	Improving the productivity of order picking of a manual pick and multi-level rack distribution warehouse through the implementation of class-based storage
Author	Felix T.S. Chan, H.K. Chan
Year	2011
Page	2686-2700
Volume	38
Edition	3
Publisher	Expert Systems with Applications
Publication Type	Journal
Publication Scope	International
	Case study
Type of Company	Retail
Area/Country	Hongkong
	Content
Background	Manual tiered warehouses require effective picking productivity by organizing storage locations according to their category and product code alphabetically or numerically, item movement types stored in the same location, and the same shelf level.
Objective	Presenting a simulation study of real cases regarding the problem of storage placement in multilevel rack warehouses and manual picking
Description/Finding	simulation results using randomized storage much worse than the implementation of the method of class-based vertical ABC. Still, the horizontal ABC method is superior to policy class-based vertical ABC.
Impact	1. Vertical ABC has the best performance in total order picking time but the worst performance in total travel distance. 2. Horizontal ABC has the opposite performance compared to vertical ABC storage. 3. Random storage has a better impact on reducing the total order-picking time than reducing the total mileage.
Research result	The key to implementing an effective storage assignment system is matching the type of warehouse storage system and the various items in a customer's order. Also, usage key performance indicators must clearly reflect the needs of the warehouse.
Excess Research	Example of a multi-level rack warehouse implementation to improve retrieval performance by conducting twenty-seven trials on various combinations of storage assignment policies, routing policies, and retrieval densities.
Research Opportunities	1. Warehouse layout design and congestion problems due to order pickers at the same time. 2. The addition of a combination of factors improves picking performance to become more comprehensive and adaptive to the diversity of warehouse operations. 3. Improved integration of warehouse activities with actual data simulations, overall logistics performance, and customer service levels.

4. Result and Discussion

As many as 26 journal articles under the specified topic were obtained as the result of a systematic review. The results will be analyzed into four parts of the analysis. The first part is the bibliographic analysis, the second part is the case study analysis, the third part is content, and the last part is an analysis of the research gap originating from previous research.

4.1. Bibliography analysis

A bibliographical analysis is initiated with the determination of the year of publication. The year ranged from 2004-2023, resulting in 26 journal publications, 22 of which are Scopus-indexed. The mapping of the year of publication can be seen in Figure 2. In 2004 one article was obtained; in 2005, one article was generated; in 2007 and 2008, two articles were filtered for each year; in 2009, one article was identified; in 2011 until 2013, resulted only a single article; in 2014 and 2015 with two articles for each year, 2016 and 2017 with single article for each year, in 2019 with four articles, in 2020 with two articles, in 2022 three articles were collected, and finally in 2023 with one article.

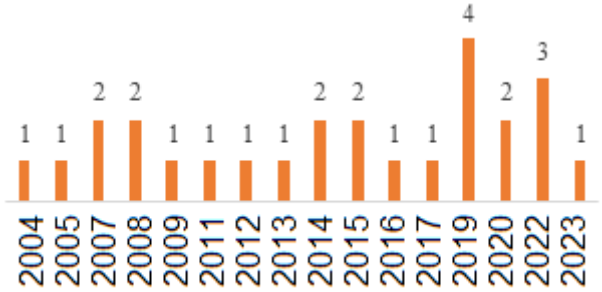

Fig. 2. Year of article publication

From the Figure 2, it is identified that the most published articles occurred in 2019, with four publications. It indicates that many articles were published on the topic of warehouse optimization in that year. They were originated from various publisher sources which can be accessed through several journal databases, namely: two articles are sourced from IFAC (International Federation of Automatic Control), one article originated from Asia-Pacific Journal of Operational Research, one article from Cluster Computing, one article from Facilities, two articles of the European Journal of Operational Research, one article is derived from Expert Systems with Applications, one article from the IEOM Society International, three articles from the IISE Transaction, one article from the International Conference on Informatics in Control, Automation and Robotics, two articles are taken from the International Journal of Advanced Manufacture Technology, one article from the International Journal of Logistics: Research and Applications, one article from the International Journal of Physical Distribution & Logistics Management, one article from the International Journal of Production Economics, three articles from the International Journal of Production Research, two articles from the IOP Conference Series: Materials Science and Engineering, two articles from Production & Manufacturing Research, and finally one article from Scientific Reports. All articles share the same type of publication, classified as a journal. While the scope of the journal is included as international journals using English in all articles.

4.2. Details of case study analysis

The rapid development of industrial companies goes hand in hand with the decreasing need for land, addressed for warehouses that are used to store finished goods and raw materials, in various parts of the country, either in Asia, Europe, UK, USA, and others. Differences in warehouse layout across countries affect the optimization level of each warehouse. Figure 3. illustrates a graph of the case study results based on 26 reviewed articles, as follows:

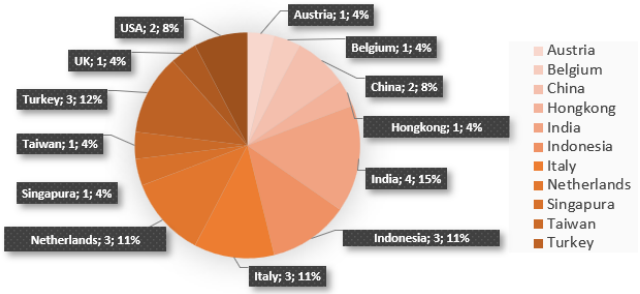

Fig. 3. Area/country of publication

From the Figure 3, it can be identified that the results of the case study on the areas/countries where articles are published are widely varied, including the percentage of 4% representing countries with one unit of journal publications originating from Austria, Belgium, Hong Kong, Singapore, Taiwan, and the UK. The next percentage was 8% of journals conducted by China and the USA. Furthermore, the countries classified in the group of 11% are Indonesia, Italy, and Netherlands. While Turkey is included as a country with a 12% percentage. The next percentage of 15% is addressed to India, which represents four units of journal publications.

The warehouse can be interpreted as a logistics system for a company, which functions as a storage place for raw materials and finished goods before being distributed to consumers. The type of warehouse will be adjusted to the type of company based on the needs of each company. Figure 4. represents an analysis of the types of companies involved in all research articles.

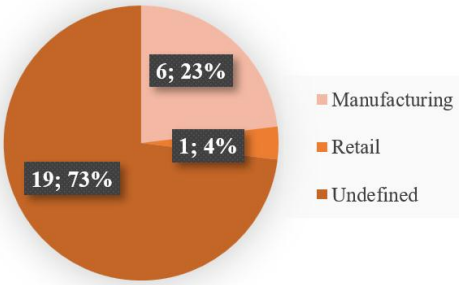

Fig. 4. The types of companies

Based on all the existing articles, the type of companies that often optimize the layout functions in warehouses is

manufacturing companies, with a percentage of 4%, followed by retail companies, with a percentage of 23%. While another 73% are companies that are not defined in the article.

4.3. Focus and content analysis

In this section, the importance of research is explained by the objectives of the 26 articles. The grouping of research objectives is categorized and presented in Figure 5.

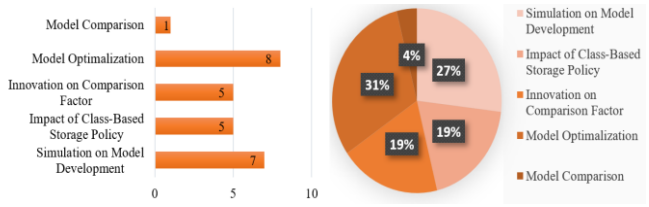

Fig. 5. Research objectives

Five objective groupings were obtained, which are, a comparison of models based on the company's needs to find an AS/RS value that is superior to the several existing models. The percentage obtained is 4%. Model optimization is the research goal with the highest score, based on the warehouse's decreased function, either in terms of distance to pick up goods, average cycle time, and operational costs. The percentage of results is 31%. Next, the innovation of a comparison factor is based on the search for new evolutions as a comparison factor so that the methods can lead to more complex and comprehensive results. The percentage of results obtained is 19%. Later is the impact of policy on class-based storage, which is based on the type of storage that can save storage space and optimize warehouse functions. The percentage obtained is 19%, an identical value to the percentage set for the research objective as comparison factor innovation. And the last grouping is model development simulation, which is based on a rapid increase in research results requiring researchers to continue making updates. The percentage is recorded as 27%, the second largest percentage value of the five groupings.

The implementation of storage assignment policies depends on the needs of warehouse operators as well as some environmental constraints, such as the size and layout of storage systems and material handling systems, as mentioned (Ekren, Sari, & Lerher, 2015). Several research findings from 26 articles are grouped into three sections, as presented in Figure 6.

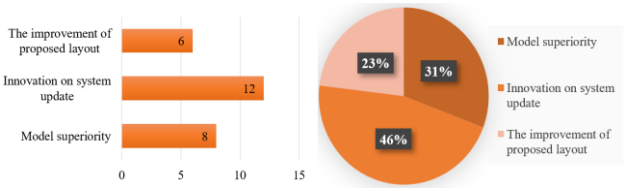

Fig. 6. Research Findings

It is identified that the first grouping of findings is an increase in proposed layouts generated from the use of research methods that affect layout improvements from prefix layouts; the resulting percentage was 23%. The second grouping is based on the findings of system update innovations which are based on research that has been carried out, proving that the existing system has several weaknesses. Hence an update is required. Later, the research can generate an output that can keep up with the development of industrial technology. The percentage is recorded in the highest value, which is 46% of articles that pay attention to innovation updates. And the last group is the advantage of the model, which is based on model comparison research, then it is found that one model has certain advantages compared to other models. The percentage obtained is 31%.

The results of optimizing the warehouse function of the 26 articles used, as shown in Figure 7. Grouped into four categories that have the highest to lowest values, namely: first, minimizing cycle time, as the result that has been widely studied in research articles. Second, the regular placement of goods creates space saving in the warehouse. Third, the results of the study were able to reduce storage mileage to minimize the AS/RS value for picking up goods. And finally, the efficiency of warehouse operational costs. Costs included in warehouse operational costs cover material handling costs. It is occurred due to material activities or raw materials being transferred from one machine to another or from one department to another (Pratama, Gozali, Daywin, & Vioren , 2022).

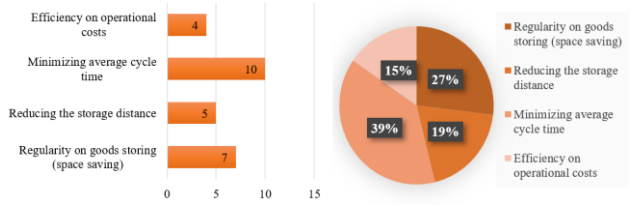

Fig. 7. Research results

Research results are grouped into four categories; the first category minimizes the average cycle time. With a total of 10 articles and a percentage of 39% as the highest percentage value. Travel time (order picking) OP shares 50% of OP activities (Ouhoud, Guezzen, & Sari, 2016). The class-based storage Policy is an inexpensive strategy to reduce fetch cycle times. The dominant collection time component is travel time (50%) because travel time spends working hours but does not add value or is a waste (Pan, Wu, & Chan, 2014). For this reason, research is needed to minimize the average cycle time. The second category is the regular placement of goods which results in space savings. Seven articles are identified with a percentage of 27%. The impact of applying the class-based storage method in this study is the similarity of the goods' placement in the cabinet in terms of the dimensions, types of goods, and the reduced utility of the warehouse area (Alfarokhi, Qurtubi, & Miranda, 2019). The key to implementing an effective storage system is matching each type of warehouse storage system and the various items in customer orders (Chan & Chan, 2011).

The third category is reducing storage mileage; the results come up with five articles that equal the percentage of 19%. Using the average mileage as the objective function is used as a mathematical formulation for the storage zone optimization problem. The average travel distance from picking is very important because it is linearly related to travel time, which is most often used as

a goal in warehouse optimization problems (Alfarokhi, Qurtubi, & Miranda, 2019). The class-based storage policy reduces travel distances by storing frequently picked-up items near Input/Output points (Berglund & Batta, 2012). The fourth category is the grouping of results based on operational cost efficiency. The number of articles discussing cost efficiency is four articles with a percentage of 15%. There are situations when space costs are significant, compared to collection costs, and thus class-based policies can also offer cost reductions through space savings. Thus, the biggest target for reducing warehouse costs is to reduce the picking distance. It is best achieved by establishing proper and regular storage locations. Determination of storage locations in the warehouse also affects the productivity of other warehouse processes (Venkitasubramony & Adil, 2008).

4.4. Research Gap

The research gap is a gap caused by differences in concepts, theories, data, and problems that occur in the results of previous studies. The research gap can be used for further research by subsequent researchers based on the selection of appropriate strategies. After carrying out a systematic review of the 26 available articles, the research gaps are formulated as in Table 3.

Table 3.
Research Gap

Opportunity	References
Development of a storage location layout design model	Eder (2022); Xu et al. (2019); Chan & Chan (2011); Alfarokhi et al. (2019); Ekren et al. (2015); Ouhoud et al. (2016); Pan et al. (2014); Adil & Rao (2013); Yu & De Koster (2009); and Petersen et al. (2004)
Development of storage types & order-picking routes	Schenone et al. (2020); Ekren et al. (2015); Pan et al. (2014); Berglund & Batta (2012); Adil & Rao (2013); Park & Webster (2007); and Manzini et al. (2015)
Operational policy-making	Le-Duc & De Koster (2005); Pratama (2022); Pan et al. (2014); Subir & Adil (2014); Zhou et al. (2022); and Manzini et al. (2007)
Investigation of the impact of design scenarios	Alfarokhi et al. (2019); Ouhoud et al. (2016); Adil & Rao (2013); Manzini et al. (2015); Gozali et al. (2020); and Nima et al. (2017)
Trial with different methodologies	Eder (2022); Pan et al. (2014); Berglund & Batta (2012); Adil & Rao (2013); and Manzini et al. (2015)
Addition of influence factors	Chan & Chan (2011); Muppani & Adil (2008); Subir & Adil (2014); Gozali et al. (2020) and Park & Webster (2007)
Addition of technology to the storage area	Ekren et al. (2015) and Park & Webster (2007)
Consideration of economic aspects	Berglund & Batta (2012)
Simulation on the potential loss of a model	Bahrami et al. (2019)

The results of the analysis of 26 research articles show research gap that previous research opportunities regarding the development of storage location layout design models meet the most gaps. It is expected that further research will apply more innovative and solutive design models aligned with the existing problems in the company. Followed by the opportunity to develop the type of storage and route for taking orders, it is done so that research can meet the right distance with the most efficient travel time. Furthermore, the making of operational policies such as routing cycle policies, alternative policies, rules for selecting raw materials, scheduling, and terms of transportation used must be further regulated to optimize warehouse functions.

Then, research opportunities may be explored on the addition of factors that influence the performance and operational costs of the warehouse. Study on relationships among sustainable design scenarios as is research on non-traditional layouts under class-based storage strategy to create a new design scenario. Furthermore, researching trials with a different methodology so that researchers understand the different basic concepts of the same research data and understand them more deeply. The more advanced application of information systems in warehouse management is a growing trend, and related new technologies will surely be useful for future decision-making (Xu, Zhao, Zou, & Li, 2019). So, research is crucial in adding technology to storage areas, such as the usage of augmented reality, the Internet of Things, cloud technology, cyber-physical systems, and Industry 4.0 in the warehousing process. Then the opportunity for economic considerations in a warehouse must be carefully calculated because it affects the overall operational costs of the company. And finally, the research opportunity to test the potential loss of the applied model since if the company cannot manage warehouse management properly, it will result in limiting the expected increase in productivity.

5. Conclusion

Based on the results of the analysis of 26 research articles using the research systematic review method. The results show that to achieve optimization of the warehouse function, there are several determining factors, such as minimizing the average cycle time of picking up goods at the warehouse, making a routing system that is appropriate to the type of warehouse, applying the model of storing goods in the warehouse using the class-based storage method, so that the goods in the warehouse are arranged based on type and dimensions, to create space savings as the initiation of optimizing warehouse functions, and efficiency of warehousing operational costs.

The foremost result or accomplished insight is concluded as the arrangement of a certain number of

research gaps over issues on storage zone function optimization in warehouses, which can be used as an opportunity to fill in the gap of the next research. The existing literature review comes up with weakness, as it only relies on four journal databases due to limited access to broader ones. Hence, it is suggested for future research to employ other reputable databases for appropriate numbers of articles, or it is advised to apply other systematic review methods for alternative perspectives of review.

References

Xu, X., Zhao, X., Zou, B., & Li, M. (2019). Optimal dimensions for multi-deep storage systems under class-based storage policies. *Cluster Computing, 22*(1), 861-875.

Venkitasubramony, R., & Adil, G. (2019). An integrated design approach for class-based block stacked warehouse. *Facilities, 37*(4), 919-941.

Chan, F. T., & Chan, H. K. (2011). Improving the productivity of order picking of a manual-pick and multi-level rack distribution warehouse through the implementation of class-based storage. *Expert systems with applications, 38*(3), 2686-2700.

Muppani, V. R., & Adil, G. K. (2008). A branch and bound algorithm for class based storage location assignment. *European Journal of Operational Research, 189*(2), 492-507.

Schenone, M., Mangano, G., Grimaldi, S., & Caglian. (2020). An approach for computing AS/R systems travel times in a class-based storage configuration. *Production & Manufacturing Research, 8*(1), 273-290.

Alfarokhi, S. L., Qurtubi, & Miranda, S. (2019). Improvement of storage system upright piano cabinet using class based storage. *IOP Conference Series: Materials Science and Engineering, 697*, pp. 1-10. Indonesia.

Le-Duc, T., & De Koster, R. M. (2005). Travel distance estimation and storage zone optimization in a 2-block class-based storage strategy warehouse. *International Journal of Production Research, 43*(17), 3561-3581.

Eder, M. (2022). An analytical approach for a performance calculation of shuttle-based storage and retrieval systems with multiple-deep and class-based storage. *Production & Manufacturing Research, 10*(1), 321-336.

Guenov, M., & Raeside, R. (1992). Zone shapes in class based storage and multicommand order picking when storage/retrieval machines are used. *European Journal of Operational Research*, 58(1), 37-47.

Ha, J., & Hwang, H. (1994). Class-based storage assignment policy in carousel system. *Computers & industrial engineering, 26*(3), 489-499.

Hwang, H., & Ha, J. (1994). An optimal boundary for two class-based storage assignment policy in carousel system. *Computers & Industrial Engineering, 27*(1-4), 87-90.

Kouvelis, P., & Papanicolaou, V. (1995). Expected travel time and optimal boundary formulas for a two-class-based automated storage/retrieval system. *International Journal of Production Research, 33*(10), 2889-2905.

Sarker, B., Mann Jr, L., & Leal dos Santos, J. (1994). Evaluation of a class-based storage scheduling technique applied to dual-shuttle automated storage and retrieval systems. *Production planning & control, 5*(5), 442-449.

Larson, T., March, H., & Kusiak, A. (1997). A heuristic approach to warehouse layout with class-based storage. *IIE Transactions, 29*(4), 337-348.

Bahrami, B., Piri, H., & Aghezzaf, E. H. (2019). Class-based storage location assignment – an overview of the literature. *International Conference on Informatics in Control, Automation and Robotics (ICINCO 2019), 1*(1), 390-397.

Suhariyanto, T. T., Wahab, D. A., & Rahman, M. N. (2017). Multi-Life Cycle Assesment for Sustainable Products: A Systematic Review. *Journal of Cleaner Production, 165*, 677-696.

Ekren, B., Sari, Z., & Lerher, T. (2015). Warehouse Design under Class-Based Storage Policy of Shuttle-Based Storage and Retrieval System. *IFAC (International Federation of Automatic Control), 48*(3), 1152-1154.

Pratama, M., Gozali, L., Daywin, F., & Vioren , V. (2022). Raw Material Warehouse Layout Design Using Class-Based Storage Method with ProModel and FlexSim Simulation at Automotive Assembling Company. *IEOM Society International, 1*(1), 2020-2132.

Ouhoud, A., Guezzen, A., & Sari, Z. (2016). Comparative Study between Continuous Models and discrete models for Single Cycle Time of a Multi-Aisles Automated Storage and Retrieval System with Class Based Storage. *IFAC (International Federation of Automatic Control), 49*(12), 1341-1346.

Pan, J. C.-H., Wu, M. H., & Chan, W. L. (2014). A travel time estimation model for a high-level picker-to-part system with class-based storage policies. *European Journal of Operational Research, 237*(3), 1054-1066.

Berglund, P., & Batta, R. (2012). Optimal placement of warehouse cross-aisles in a picker-to-part warehouse with class-based storage. *IISE Transaction, 44*(2), 107-120.

Venkitasubramony, R., & Adil, G. K. (2008). Class-based storage-location assignment to minimise pick travel distance. *International Journal of Logistics: Research and Applications, 11*(4), 247-265.

Adil, G. K., & Rao, S. S. (2013). Class-based storage with exact S-shaped traversal routeing in low-level picker-to-part systems. *International Journal of Production Research, 51*(16), 4979-4996.

Yu, Y., & De Koster, R. B. (2009). Optimal zone boundaries for two-class-based compact three-dimensional automated storage and retrieval systems. *IISE Transaction, 41*(3), 194-208.

Petersen, C., Aese, G., & Heiser, D. (2004). Improving order-picking performance through the implementation of class-based storage. *International Journal of Physical Distribution & Logistics Management, 34*(7), 534-544.

Park, Y., & Webster, D. (2007). Design of class-based storage racks for minimizing travel time in a three-dimensional storage system. *International Journal of Production Research, 27*(9), 1589-1601.

Manzini, R., Accorsi, R., & Gamberi, M. (2015). Modeling class-based storage assignment over life cycle picking patterns. *International Journal of Production Economics, 170*(C), 790-800.

Subir, S. R., & Adil, G. K. (2014). Class-Based Storage Assignment in a Unit-Load Warehouse Employing AS/RS with Inventory Space Allocation Considering Product Specific Setup to Holding Cost Ratio. *Asia-Pacific Journal of Operational Research, 31*(5), Asia-Pacific Journal of Operational Research.

Zhou, L., Zhao, J., Liu, H., Wang, F., & Yang, J. (2022). Stochastic models of routing strategies under the class-based storage policy in fshbone layout warehouses. *Scientific Reports*, *12*(1), 1-17.

Manzini, R., Gamberi, M., Persona, A., & Regattier. (2007). Design of a class based storage picker to product order picking system. *International Journal Advanced Manufacture Technology, 32*(1), 811-821.

Gozali, L., Marie, I. A., Kustandi, G. M., & Adisu. (2020). Suggestion of Raw Material Warehouse Layout Improvement Using Class-Based Storage Method (case study of PT. XYZ). *IOP Conference Series: Materials Science and Engineering, 1007*(1), 1-10.

Nima, Z., Yugang, Y., & René, B. d. (2017). Optimal two-class-based storage in a live-cube compact storage system. *IISE Transaction, 49*(7), 653-668.

Suhariyanto, T. T. (2019). Introduction to Systematic Literature Review (SLR). *Training Materials, June 22, Yogyakarta*.

Fitri, A., Moengin, P., & Puspitasari, F. (2023). Simulation Model Design and Improvement of Raw Material warehouse layout with class-based storage method: A case study. *International Journal of Advanced Engineering and Management Research, 8*(1).

Harzing, A. (2007). *Publish or Perish*. Retrieved from https://harzing.com/resources/publish-or-perish