Global Journal of Business, Economics, and Management: Current Issues

Volume 12, Issue 3, (2022) 296-305

www.wjbem.eu

Current studies on storage location assignment problem

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Suggested Citation:

Şenyiğit, E. & Arsav, M. S. (2022). Current studies on storage location assignment problem. *Global Journal of Business, Economics, and Management: Current Issues. 12*(3), 296-305. https://doi.org/10.18844/gjbem.v12i3.7205

Received from July 16, 2022; revised from September 12. 2022; accepted from October 12, 2022.
Selection and peer-review under the responsibility of Prof. Dr. Andreea Claudia Serban, Bucharest Academy of Economic Studies, Romania.

Abstract

Although operations seem more important than everything in a business operation, warehouse management has great importance to the success of a business operation. Storage location assignment is very important because of the uncertainty in the number of incoming products, the necessity of answering unknown customers' demands and the speed rate of response to customer demands. Besides, several factors affect warehouse management. Assigning products to appropriate locations is one of the most important and complex. This study aims to present recent academic works on the storage location assignment problem published from 2018 to 2021. These problems are assigned accordingly. Methods of solution, goals and some related considerations are considered while investigating the works. Recommendations are provided in the conclusion. Based on the reviewed articles, warehouse capacity, market, products, logistics resources and operational configuration are taken into account as restrictions or considerations.

Keywords: Location, logistics, storage, warehouse management;

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1. Introduction

According to Reyes et al. (2019), in supply chain management (SCM), storage is defined as buffer products that are ready to supply to customers whenever they are needed; however, they should be ready to satisfy customer needs as soon as possible. Frazelle et al. (2007) say there are some critical points on storage. These are transaction size, complex storage situations and different features of different products. Regarding national and international orders, response to these orders is another different problem since customer goodwill should always be kept high (Reyes et al., 2019).

1.1. Literature review

1.1.1. Storage location assignment problem (SLAP)

SLAP is related to allocating different kinds of products into different locations. While doing this assignment, SLAP aims to use the area as effectively as possible. Besides this, the problem tries to optimise costs that occur due to material handling and utilisation of area. This problem depends on some parameters, such as the design of the storage field, availability of storage field, capacity, physical conditions of warehouses and physical features of products, product demands and incoming times of products (Reyes et al., 2019). Frazelle (1989) defines SLAP as an NP-Hard problem since there is a massive number of products and huge warehouse spaces, and when we try to combine all these things, logarithmic numbers come out.

Da Silva et al. (2015) say that in the past, warehouse operations seemed to be very basic things to figure out; however, as technology advances, warehouse operations became more complex than ever. Fontana and Cavalcante (2014) also think warehouse operations have been becoming more complex every single day since technological developments provide more efficient and effective solutions to solve warehouse problems.

When products come to the warehouse, there are a lot of things to consider. On one hand, picking and retrieval time is important and, on the other hand, classifying incoming products is complex and requires planning for each warehouse (Fontana & Cavalcante, 2014). Fontana and Cavalcante (2013) claim that the efficiency of operations is based on the planning of the layout and warehouse systems.

Different storage strategies can be implemented, but these decisions are called operational decisions. Storage systems are divided into three categories: fixed or dedicated, random or variable, and class-based storage (CBS) (Fontana & Cavalcante, 2013).

When someone establishes a new warehouse, they should consider some points. First of all, warehouse locations must be chosen appropriately and carefully to maintain fast, cheap and safe retrieval operations. SLAP is highly affected by some features, such as products features and size, layouts of the storage systems, material handling systems and demands of products (Micale et al., 2019). Zhang et al. (2019) say that order picking time is one of the most important things in warehouse management and it affects SCM.

1.1.2. Motivation of a review paperwork on SLAP

SLAP is a kind of a problem that has various applications in practice. Due to this characteristic problem, it is essential to solve the problem in this area to increase the efficiency and effectiveness of the warehouse operations. SLAP has several application areas in practice, such as warehouses of raw materials, distribution centres, hospitals, parking lots and so on (Reyes et al., 2019). Besides, we worked on two papers previously (Senyigit & Arsav, 2019a, 2019b) that are similar to this subject. All this evidence gives us motivation to find an appropriate solution for this problem since theoretical and practical bases are relevant to each other.

1.2. Purpose of the study

We reviewed the last publications regarding SLAP and present all the data in this paper. We explain about SLAP below.

2. Materials and methods

We utilised a systematic literature review (SLR) for this paper. The advantages of SLR are to find and fulfil every research question, review the topic appropriately, make it easier to understand specific theoretical approaches, provide information regarding references and analyse data outcomes in qualitative and quantitative ways. Apart from these, the following specific research questions were asked and answered (Reyes et al., 2019):

- How do people assign SLAP?
- Which types of methodologies have been utilised to find a solution for SLAP?
- Which types of performance criteria have been optimised?
- What types of limitations and restrictions have been set for the suggested solutions?

To answer these research questions, we used the following steps based on Seuring and Gold (2012) and Seuring et al.'s (2005) studies:

- Material collection (MC).
- Descriptive analysis (DA).
- Category selection (CS).
- Material evaluation (ME) (Reyes et al., 2019).

2.1. Material collection

The scope of the literature review was restricted to academic papers published in academic journals with academic relevance to our research subject. To reach these academic journals, the Scopus database was utilised; using this database gave us high accessibility to relevant articles. SLAP, storage assignment and warehouse management were the keywords used to access relevant articles regarding our research topic. We focused mostly on articles. While doing this research, we considered the 4-year time frame between 2018 and 2021. Gu et al. (2007) had conducted a literature review work on SLAP for 2004 and Reyes et al. (2019) exhibited their work for SLAP between 2005 and 2017. In this respect, our study is complementary to these two studies. A search string was utilised to simplify the searching process. This search string is as follows:

Search string: TITLE-ABS-KEY (Storage location assignment problem or Storage assignment or Warehouse management) AND (LIMIT-TO (PUBYEAR,2021) OR LIMIT-TO (PUBYEAR,2020) OR LIMIT-TO (PUBYEAR,2019) OR LIMIT-TO (PUBYEAR,2018)) AND (LIMIT-TO (DOCTYPE,"ar")) (Reyes et al., 2019).

2.2. Descriptive analysis

In this section, according to the outcome of our research, articles have been classified and categorised according to the following factors, which were inspired by Reyes et al. (2019):

- Distribution of publications per year.
- Published journal names of reviewed articles.
- Utilised research methods in reviewed articles.

2.3. Category selection

Figure 1 shows how the articles are classified.

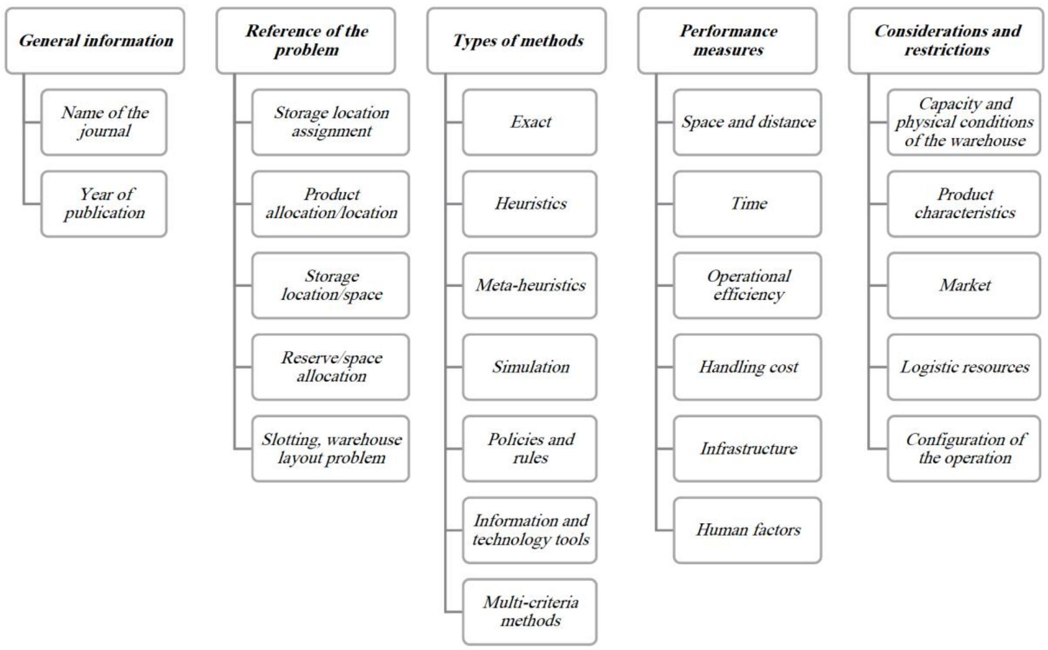

Figure 1. Classification of articles. Source*:* Reyes et al. (2019)

There are five main topics for comparison (Reyes et al., 2019). Let us get into more details about them.

General information: This category contains the name and published year of the articles.

Reference of the problem: This category shows which type of terminology or conceptual word was utilised to define SLAP. The following terms were used: SLAP, assignment of products to storage locations, warehouse management, storage assignment, warehouse layout model, location assignment, slotting, order picking, storage strategies, warehouse operations, clustering and storage system.

Types of methods: This category encompasses different types of global solution methods for SLAP, such as exact (EX), heuristics (HEU), meta-heuristics (MHEU), simulation (SIM), policies and rules (SP&R), other trends and support tools (OT) and multi-criteria decision-making methods (MC).

Performance measures: In this section, we specify articles' objectives and their functions to optimise. These objectives can be put in order as follows: space and distance (SPD), time (TMP), operational efficiency (OE), material handling costs (CT), infrastructure (INF) and human factors (HF) (Reyes et al., 2019).

Considerations and restrictions: In this section, we cover the most important restrictions and limitations, for example, capacity and physical conditions of the warehouse (CAP), product (PROD) characteristics, market (MR), logistics resources (REC) and operation configuration (OPE) (Reyes et al., 2019).

2.4. Material evaluation

We chose articles and made our review based on the criteria which are mentioned earlier in Section 2.1. These criteria were used to maintain reliability and relevance. For a question, there might be more than a solution. At this point, both solution methods have been counted separately for their category.

3. Results

As described earlier in Section 2, we applied the research methodology and found 21 articles in the first search from the Scopus database. After further research, we select 14 of these 21 articles based on their quality and relevance. Between 2018 and 2021, 14 articles were reached. We see an average of 3.5 articles published per year during these 4 years considered for this research. Figure 2 shows the distribution of papers during this 4 years' timetable. These 14 articles come from 12 different scientific journals.

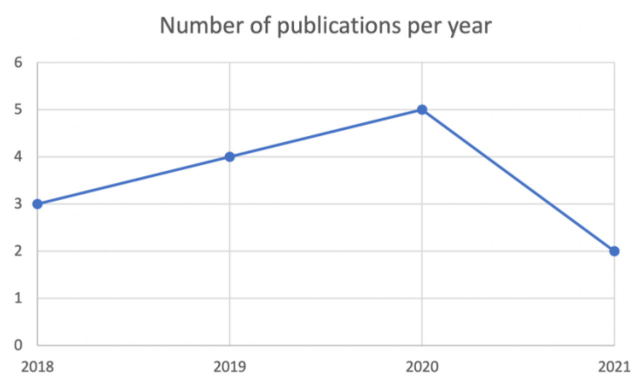

Figure 2. Distribution of publications per year

Micale et al. (2019) utilised a combination of interval-valued ELECTRE TRI and interval-valued TOPSIS as a multi-criteria decision-making method to solve SLAP. To do this, they used the ELECTRE TRI method to assign a product to an appropriate shelf level and use the TOPSIS method to find the best possible storage location for every product. While doing this, they consider both efficiency (weight, space and demand) and economic factors (profitability and popularity). They used a local logistic services company's data to apply the specified method above.

Ballestín et al. (2020) took storage and retrieval problems into account in a real warehouse by using a random storage system. They called this problem a storage and retrieval assignment problem with heterogeneous forklifts (SRLAP-HF). SRLAP-HF, basically, chooses storage/retrieving locations for pallets and assigns these pallets to forklifts to deal with them by considering employed time minimised. For this problem, Ballestín et al. (2020) were inspired by a warehouse company that produces beauty products.

Guerra-Olivares et al. (2018) worked on an outbound container location problem in Shanghai maritime terminals. To solve this problem, Guerra-Olivares et al. (2018) divided the problem into two phases. For the first phase, a mathematical model is presented and in the second phase, a heuristic algorithm whose objective is to minimise re-handling operation during loading is utilised to reach the object of the problem. Based on the experiments' results, diagonal stacking gave the best solution for this problem (Guerra-Olivares et al., 2018).

Bortolini et al. (2020) aimed to minimise travel distance and required storage space with a two-step procedure. This research is inspired by harvesting machines from the agricultural sector (Bortolini et al., 2020). Van Gils et al. (2019) studies are inspired by a real-life business-to-business spare parts warehouse. They used an empirically driven SIM method which is new in the warehouse area. This study shows the similarities and differences between storage location and warehouse management systems (WMS) (Van Gils et al., 2019).

Arunyanart et al. (2019) worked on a beverage company's distribution centre in Thailand to make its warehouse management more efficient. To achieve this, several methods are applied to find optimal safety stock, maximise utilisation of space and make storage location assignment best for every product. Arunyanart et al. (2019) applied a warehouse layout model with the ABC analysis technique to minimise total travel distance.

Fontana et al. (2020) present a multi-criteria assignment method to solve SLAP while considering CBS to improve warehouse management. To do this, they used ELECTRE TRI as a multi-criteria decision-aiding method and multi-objective evolutionary algorithm (MOEA). By using these methods, they found a SLAP solution by considering stock-keeping unit (SKU) characteristics (Fontana et al., 2020). Yan et al. (2018) focused on the storage of products in a stereoscopic storehouse. To do so, they used the improved adaptive genetic algorithm as a solution method. This method maintains warehouse efficiency and stores similar products close to each other (Yan et al., 2018).

Chen et al. (2021) investigated SLAP to find efficient storage for Ro-Ro terminals. They modelled car groups to minimise the total distribution of cars. A hierarchical two-stage exchange strategy is designed and utilised to find the optimal car layout to get the optimal distribution of cars. Since this problem's size is big, it is hard to solve it to avoid this possible problem; they used a rolling-horizon heuristic approach. They made a lot of experiments and those experiments proved that the proposed method can present an effective car assignment plan in Ro-Ro terminals. Finally, they applied their method to the Shanghai Haitong Ro-Ro terminal (Chen et al., 2021).

Viveros et al. (2021) developed the SLAP variable height approach and divided this problem into four sub-problems. These sub-problems are solved simultaneously. This project aimed to find a solution for the multi-level SLAP for SKU pallets. To fulfil this goal, they tried to make better picking operations and minimise the travel times of cranes on the route. They mainly aimed at reducing costs by reducing movements (Viveros et al., 2021).

Saleet (2020) says that SCM is more important than ever for WMS due to the COVID-19 pandemic. Therefore, Saleet (2020) used a generic solution to solve SLAP, which is a smart logistics solution using data analytics and genetic algorithms. In this method, an association-based assignment algorithm accommodates SKUs close to each other according to the order frequency together. In this manner, this solution helps staff when they pick multiple products per order by reducing the distance of movement and time to bring back the products. Saleet (2020) aimed to optimise SLAP by using a genetic algorithm and we think the author was pretty much successful since there is only a 5.6% difference between the optimal solution and the solution which is proposed.

Hirata et al. (2019) worked on a case study that is related to an automobile factory to reduce total operational time. They have a problem with loading and unloading pallets in the reserve area because of too much handling time spent. Increasing stored parts in the reserve area over time makes the situation harder and because of this, stacking of parts should be prevented to create more space but this situation leads to an increase in travel time for forklifts. So, Hirata et al. (2019) suggested two policies, which are the storage efficiency priority policy and the handling efficiency priority policy to reduce handling time.

Lee et al. (2020) designed a systematic and integrated approach to storage location assignment to improve warehouse order picking operation's efficiency. Thereby, they can reduce the significant amount of travel costs. To minimise travel time and picking delays, this problem is divided into two stages: clustering and assignment. On one hand, the clustering stage is solved by using MOEAs and, on the other hand, each cluster is assigned to applicable storage locations (Lee et al., 2020).

Yuan et al. (2019) focused on storage decisions since these decisions have a great impact on the travel time and workload of robotic drivers. Yuan et al. (2019) compared velocity-based storage policy and random storage policy to maintain maximum improvement from storage systems. They applied their approach to pod storage decisions for a semi-automated storage system based on velocity-based storage policies.

Table 1 shows the category selection that is stated in Section 2.3 in detailed results.

Table 1. Classification of selected articles

Authors	**Solution methods**							**Performance measures**						**Restrictions and considerations**					**Journal name**
	EX	**HEU**	**MHEU**	**SIM**	**SP&R**	**OT**	**MC**	**SPD**	**TMP**	**CT**	**OE**	**HF**	**INF**	**CAP**	**MER**	**PROD**	**REC**	**OPE**	
Micale et al. (2019)							X	X						X					Computers and Industrial Engineering
Ballestín et al. (2020)	X	X	X	X				X	X		X			X		X			International Transactions in Operational Research
Guerra-Olivares et al. (2018)	X	X						X			X							X	International Journal of System Assurance Engineering and Management
Bortolini et al. (2020)	X							X					X	X		X	X	X	Assembly Automation
Van Gils et al. (2019)	X			X	X			X	X				X	X					Transportation Research

Arunyanart et al. (2019)	X							X			X		X	X	X		Asia-Pacific Journal of Science and Technology
Fontana et al. (2020)	X				X		X	X		X	X					X	Revista Investigacion Operacional
Yan et al. (2018)	X		X	X			X	X		X			X			X	Journal of Intelligent Manufacturing
Chen et al. (2021)	X	X						X		X	X	X	X		X	X	Transportation Research
Viveros et al. (2021)	X				X	X		X	X	X	X		X				Applied Sciences
Saleet (2020)	X	X				X		X	X				X		X	X	International Journal of Engineering Research and Technology
Lee et al. (2020)	X	X		X	X			X	X	X						X	Computers and Industrial Engineering
Hirata et al. (2019)					X			X	X		X					X	Journal of Japan Industrial Management Association
Yuan et al. (2019)					X	X			X		X						Production and Operations Management

4. Conclusion

This work provides an academic review on SLAP by applying the method which is proposed by Seuring et al. (2005). By using this method, we reviewed 14 articles that are related to SLAP and classified these articles based on methods of solution, performance measures and restrictions or considerations. There are different types of terminology for SLAP, such as storage location, product location or slotting etc. We classified the problem into the following seven problem types: exact, heuristics, meta-heuristics, simulation, policies and rules, other trends and support tools, and multi-criteria methods. On the other hand, space and distance, time, costs, operational efficiency, human factors and infrastructure are considered to be performance measures. Lastly, warehouse capacity, market, products, logistics resources and operational configuration are taken into account as restrictions or considerations. We focused on journal papers in this work, but graduate thesis or other academic works can be added to extend the scope of this work for future research.

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