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Review of Optimized Warehouse Layouts: Design and Configuration Strategies for Improved Efficiency

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Abstract:

The layout and design of a warehouse are crucial in enhancing operational efficiency, managing costs, and increasing productivity within supply chain networks. In today's rapidly changing markets, optimizing warehouse layouts is vital for businesses to stay competitive. An efficiently designed warehouse optimizes space utilization, improves material flow, handling times, and minimises operational costs, ultimately speeding up order fulfillment and improving customer satisfaction. This review focuses on key aspects of warehouse optimization, such as the strategic arrangement of storage racks, and workstations, while accounting for factors like inventory turnover, product types, and material handling equipment. Moreover, the study explores modern technologies, including warehouse management systems and lean methodologies, as tools to enhance warehouse efficiency. It is also addressed, covering techniques like slotting optimization and inventory management for better resource allocation. Across various storage settings, this review outlines strategies to increase capacity and efficiency, offering valuable insights for businesses aiming to improve their warehouse layouts and overall supply chain performance.

KEYWORDS:* *Warehouse Management, Linear Programming Model, Supply Chain Management, Layout and design of Warehouse.

1. Introduction

The layout and design of a warehouse play a crucial role in driving operational efficiency, cost control, and overall productivity within supply chain networks. In today's rapidly evolving markets, optimizing warehouse layouts has become essential for organizations to maintain competitiveness and improve performance[8]. A well-designed warehouse layout maximizes space utilization, streamlines material flow, reduces handling times, and lowers operational costs, contributing to faster order fulfillment and improved customer satisfaction. Warehouse optimization requires careful analysis of key factors such as the arrangement of storage racks, the positioning of workstations, and the layout of aisles. By strategically organizing these components, businesses can create a layout that enhances storage capacity, improves accessibility, and ensures efficient workflow [2][12]. This also includes considerations like inventory turnover rates, product types, and material handling equipment to ensure resources are used effectively. This study explores optimized warehouses' design and configuration strategies, examining their impact on metrics such as space utilization, worker productivity, and cost efficiency. Additionally, it highlights the use of modern techniques like automation, warehouse management systems, and lean practices to improve warehouse operations further[3]. By understanding the complexities of warehouse layout optimization, businesses can make informed decisions to enhance their supply chain performance [4]. Storage optimization is the process of identifying the most effective ways to utilize storage resources, whether in a warehouse, data storage system, or cloud environment. The goal is to improve capacity, utility, and efficiency by determining the optimal allocation and organization of stored items [5]. Different methods are applied based on the specific needs of the storage system. For example, warehouse storage optimization focuses on reducing storage costs, maximizing space utilization, simplifying item retrieval, and improving overall organization [6]. This involves developing a functional layout and determining the best item placement strategies using techniques like slotting optimization and inventory management systems [7].

In data storage systems, the primary aim is to enhance storage efficiency and retrieval speed while minimizing costs [8]. Techniques such as data compression, deduplication, tiered storage, and lifecycle management help allocate data to the most appropriate storage media based on its importance and access frequency [9]. Overall, storage optimization is critical across various domains to ensure effective resource management, cost reduction, and operational efficiency [10]. Some crucial areas for optimization include:

1.1. INVENTORY MANAGEMENT: Effective inventory management is essential for warehouse optimization [11]. This includes maintaining accurate stock records, implementing inventory control methods such as analysis optimization, determining optimal reorder points, and removing obsolete items. Employing inventory control systems or warehouse management software can significantly enhance these processes [12].

1.2. SPACE UTILIZATION & LAYOUT: Maximizing space utilization ensures all available areas are used efficiently [13]. An optimized warehouse layout, with strategically placed workstations, storage racks, and equipment, helps streamline worker movement and reduce congestion [14].

1.3. WORKER OPTIMIZATION: Assessing workforce demand and scheduling ensures sufficient staffing during peak times [15]. Proper training enhances employee skills and productivity, while performance metrics and incentive programs can motivate staff and reward goal achievement [16].

1.4. ORDER FULFILMENT: Improving order-picking and packing processes boosts efficiency and reduces errors [17]. Methods like pick-to-light systems, zone picking, and bulk picking can streamline tasks. Optimizing packing procedures also maximizes available space and ensures product safety during transportation [18].

2. Literature Review

- Dauod et al. (2017) present a detection of the community & an approach of IP to analyze & optimize the storage assignment of the warehouse for the operation of order picking. This storage assignment was the key warehouse management function that widely impacts the complete productivity of order picking. This insufficient storage leads to a high frequency of traffic crowding & decisions of low routing - so the optimization of the location of the product was critical. This assignment was challenging because it required the evaluation of big data. To analyze the data accurately, the network community detection was used to take out the relationship b/w the items. For this, the "integer programming model" was used to evaluate the optimized storage location. This approach reduced the congestion by 60% while the maintaining time of order picking.
- Kantasa-ard (2017) conducted this case study with the aim of improving the manufacturing & sales of the automotive spare parts company. It was not possible to stock & replenish all the logistics for the stocks of automotive spare parts because the space of the existing warehouse was limited. For this purpose, the company decided to relocate the raw material & prepared products from the existing warehouse to new warehouse. For these reasons, author proposed an optimization model to find the solution for the utilization of space & optimize the allocation of the no. of spare parts pallets. This model is used in the Excel Solver with the linear programming function. In the result warehouse has sufficient space for the storage to efficiently organize and store the automobile spare parts. In addition, this study has estimated the total budget of the trucks which was more precise. It has also estimate the total transportation cost which was 33% less than the original cost.
- Khan (2014) conducted a study for the planning & result in optimize solutions to various problems. In this study, the authors used the types of equipment of modern computing. To optimize the transportation the LPM (Linear Programming Method) was used. The author takes the real application problem of TP (Transportation problem) of the warehouse of the mosquito's company. For the optimization of transportation costs, the distributor used Linear Programming. Excel solver was also used to solve the problem. This model is helpful to optimize the total transportation cost.
- Khannan et al. (2018) discussed their problems with the allocation & placement of commodities in the warehouse. The goal of this research is to evaluate the allocation & placement of commodities in warehouses related to the flow type of the product with the optimized total cost of material handling. In this quantitative research, the authors used a mathematical model for the optimization & also used LINGO 11.0 for the evaluation of the optimization model. In the result optimized cost of material handling is Rs. 43.079.510 while the previous cost was Rs. 49.869.728. These models save Rs. 6.790.218.
- Kovács (2011) addressed the storage assignment problem in the warehouse distinguished by the multi-command picking & serving by logistics of Milkrun. According to the predetermined schedule vehicles travel from one location to another b/w the warehouse & the plant production facilities, frequently using multiple routes to serve various departments. The linked storage assignment problem becomes a special case when author suppose that a request probability could be allocated to every single item & each cycle. For optimized the order cycle time & the effort of order picking a (MILP) mixed Integer Programming Model was proposed for the finding of a policy of the class-based storage. The result shows that the approach can be attained up to 36% to 38% decrease the order cycle time.
- Manoharan et al. (2022) conduct a study that deals with the two models- Linear programming (LP) model & decision-making model. In warehouse the maximum quantity of product can be stored which was provided by the decision maker with the help of LP model. Rough Analytical hierarchy process (AHP) and rough technique of TOPSIS is used to evaluate the well-defined pallet on the rack. Authors observed that the implementation of enhancement the storage facility of warehouse. It is helpful to increase the production as well as taking optimal decisions.
- OBI-ANIKE & OKAFOR (2019) conducted this study that aims to demonstrate the usefulness of the linear programming (LP) model as a problem-solving & technique of decision-making in the industry for sustainability in Nigeria. It was highlighted & illustrated how LP techniques could be used for sustainable decision-making. For this, the author proposed that the linear programming (LP) technique was an effective tool for 12 decision-making in Nigerian industries because of the creation of jobs, increased productivity & economic sustainability. This study deals with the level of product A & level of product B. The combination of products A & B gives the 4 options. The first option gives the (0,0), the profit value was 0. The 2nd option gives (800:400), the profit value was 2000. 3rd option gives (1050:150), the profit value was 1875 & the 4th option gives (600:0), the profit value is 900. It shows that the production of month for products A was 800 units & the products B was 400 units. Hence the maximum profit is 2000. Hence the linear programming techniques give valuable techniques for sustainability.

- Perera et al. (2022) conducted a study to compare the previous methods of space allocation by using the Linear Programming Model (LPM) & Goal Programming Model (GPM). These models were used for space allocation of warehouses by well-defined palletizing. Different Parameters were included in the present study - brand types, types of order, and groups of pallets. In the present study authors mainly focused on optimizing of ground floor space. GAMS software, Microsoft Excel add-in, solver, CPLEX 12.6 solver was used for the allocation of warehouse space. Results showed that the both Linear programming model & Goal programming model were efficacious methods for optimizing the total pallets to satisfy the demand of any type of product.

- Geraldes et al. (2012) Warehouses serve as essential hubs within supply chains, contributing significantly to operational efficiency. With today's rapidly evolving markets, organizations must continually evaluate and adjust their warehouse strategies to meet changing demands and managerial goals. This paper introduces a mathematical programming model designed to optimize product placement, allocation to specific functional areas, and the sizing of these areas within a warehouse. A mixed-integer linear programming (MILP) model is proposed to balance various warehouse-related costs and create an optimal layout that meets throughput needs. By considering trade-offs among different costs, the model provides a comprehensive solution to enhance warehouse performance and support effective management.
- Öztürk et al. (2019) Warehouses are a critical component of supply chains, with efficient layout design reducing both delivery times and storage costs. This study addresses the warehouse layout problem in a ceramic factory with multiple warehouses and diverse raw materials. A multi-objective mixed-integer mathematical model is proposed to optimize two key goals: minimizing the transportation distance between two warehouses and four factories, and minimizing the shelf space used. Given the NP-Hard classification of the problem, a heuristic algorithm has been developed to solve large-scale instances. Additionally, a decision support system (DSS) with a user-friendly interface is proposed for factory engineers. The DSS enhances warehouse efficiency and enables systematic storage, resulting in a 61% reduction in total transportation costs.
- Zhang et al. (2017) This research explores a real-world challenge in production warehousing, where a company consistently faces difficulties in finding sufficient space for products and managing inventory effectively. To address this, we present an integrated approach that combines warehouse layout optimization with the capacitated lot-sizing problem, two areas often handled independently in previous studies. A mixed-integer linear programming (MILP) model is formulated to minimize the total costs associated with production and warehouse operations. Given the large-scale nature of the problem using real-world data, conventional optimization solvers are insufficient. Therefore, we propose an innovative Lagrangian relax- and-fix heuristic, along with several variant methods, to tackle the complexity of the problem. Initial numerical results highlight the efficiency of these heuristic techniques in solving the large-scale scenario, offering key insights into enhancing both warehouse and production management. This approach provides a cost-effective, streamlined solution to the combined warehousing and production challenges faced by the company.

Table 1. Details of different parameters considered in various studies and model used in study.

S. No.	Author	Year	Approach	Conclusion
1	Dauod et al.	2017	A community detection & integer programming approach.	This approach reduced the congestion by 60% while the maintaining time of order picking.
2	Kantasa-ard	2017	OptimizationModel using with the linear Programming function in the Excel Solver	The warehouse has sufficient space for the storage to be efficiently organized and store the automobile spare parts along with the estimated total transportation cost of 33% less than the Original cost.
3	Khan	2014	Linear Programming Model & Excel Software	It is helpful to optimize the total Transportation cost.
4	Khannan et al.	2018	A mathematical model & LINGO 11.0 software.	The optimized cost of material handling is Rs. 43.079.510 while the previous cost was Rs. 49.869.728. These models save Rs. 6.790.218.
5	Kovács	2011	Mixed Integer Programming Model	The approach can attain up to 36% to 38% decrease the order cycle time.
6	Manoharan et al.	2022	Linear programming model, AHP model and TOPSIS model	The understanding for rack selection can be optimized by using the models of fuzzy scales & models of evaluation theory.
7	OBI-ANIKE & OKAFOR	2019	Linear Programming Sustainability	A good mathematical decision-making model ought to be used by the producers & owners of the Companies in their daily operations.
8	Perera et al.	2022	Linear programming model and Goal programming model, GAMS software, Microsoft Excel add-in, solver, and CPLEX 12 were used for the result.	LPM & GPM are the efficacious solutions for optimizing the total pallets required to satisfy the demand for every type of product.
9	Geraldes et al.	2012	Mixed-integer linear programming model & LINGO 12.0 Solver	This model integrates the size of functional areas & capacity of external storage.
10	Öztürk et al.	2019	multi-objective mixed-integer linear mathematical model	Warehouse efficiency is improved, leading to more organized storage and a 61% reduction in overall transportation costs.
11	Zhang et al.	2017	(MILP) Mixed integer linear programming model	It verified the various sizes of Instances.

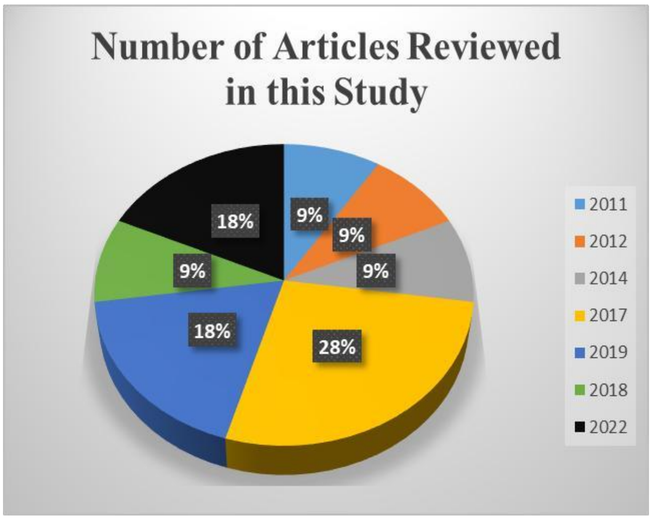

Figure 1. Pie chart of number of researches reviewed with respect to time period considered in this study.

The sky blue colored area in the pie chart here represents the number of studies, considering data from the year 2011 for the study while the orange color area represents data from the year 2012, and the Gray color area represents data from 2014 was considered. The yellow area represents the data of the year 2017 which is dominant as compared to the studies in another year, the dark blue color area represents data of 2019, the green area represents the data of 2018 the black area represents the data of 2022 as shown in Figure 1.

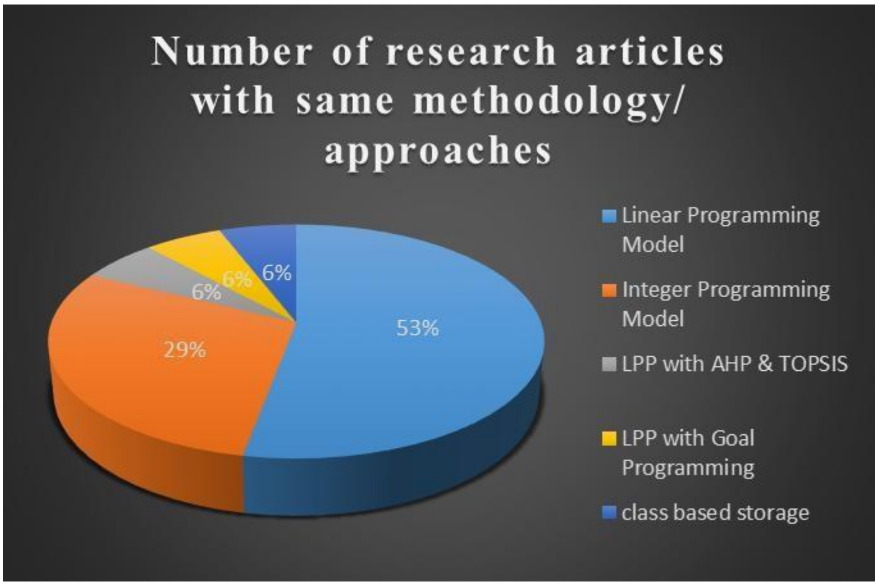

Figure 2. Pie chart of numbers of research papers with the same methodology considered in this study.

The sky blue colored area in pie chat represents the paper with Linear Programming Model while the orange color area represents the paper with Integer Programming Model, the Gray color area represents the paper related to Linear Programming Model with AHP & TOPSIS, the yellow area represents the paper with Linear Programming & Goal Programming Model and the dark blue area represents the paper with class-based storage, as shown in Figure 2.

3. Conclusion

In summary, warehouse layout and design are crucial for enhancing operational efficiency, controlling costs, and boosting productivity within supply chain networks. By strategically arranging storage racks, workstations, and aisles, businesses can optimize space usage, streamline workflows, and reduce handling times, leading to quicker order fulfillment and improved customer satisfaction. Effective warehouse layout also considers factors like inventory turnover, product types, and material handling equipment to ensure resources are used efficiently.

Additionally, integrating modern technologies such as automation, warehouse management systems, and lean practices can further enhance warehouse performance by minimizing errors and increasing productivity. Storage optimization goes beyond space maximization—it improves accessibility, cuts costs, and simplifies item retrieval. By adopting optimized warehouse layout strategies, companies can make informed decisions that support their business goals, resulting in improved supply chain performance and substantial cost savings.

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