Communications on Applied Nonlinear Analysis
ISSN: 1074-133X
Vol 31 No. 3s (2024)

An Efficient Technique for Arranging Various Commodities in a Warehouse

Chhavi Gupta[1], Dr. Vipin Kumar[2] and Dr. Kamesh Kumar[3]

[1,2,3]Department of Mathematics, Faculty of Engineering, Teerthanker Mahaveer University, Moradabad, India.

Article History:

Received: *15-04-2024*

Revised: *26-05-2024*

Accepted: *14-06-2024*

Abstract: Warehousing encompasses all the material handling tasks conducted within the confines of a supply chain's warehouse. Typical warehouse operations include complex allocation decisions that have room for optimization. This paper undertakes optimization models proposed in recent literature for allocating warehouse space. The main objective is to compare previous research on optimizing warehouse space and to elaborate warehouse space optimization using the (LP) linear programming. The model calculates the daily pallet requirements based on daily demand and various warehousing operation constraints in a multi-product manufacturing setting, providing feasible solutions that meet all constraints. The research is expected to serve as a point of reference for future research in this field. The research presents a simple and efficient (LP) linear programming model for optimizing warehouse storage space through effective palletization.

Introduction: Warehousing kept all the activities related to material handling that occur within a warehouse.A Highly Effective Method for Organizing Diverse Products in Warehouses using Linear Programming (LPP)'. This groundbreaking strategy enhances warehouse design, optimizing space usage while reducing operational expenses. Utilizing LPP, it allocates goods strategically, considering demand trends and operational limitations. By harmonizing storage needs with operational effectiveness, this method provides a structured approach to bolster warehouse management. Its adoption ensures smoother logistics, heightened inventory management, and increased productivity. This study introduces an innovative framework set to transform warehouse functions, paving the way for more streamlined and proficient supply chain operations.

Objectives: Objective: Create a methodical strategy to enhance warehouse layout and storage efficiency by employing innovative methods such as Linear Programming (LPP) to strategically distribute commodities, boosting operational effectiveness, and elevating supply chain productivity.

Methods: By applying a Linear Programming (LP) model, optimize the area in the palletizer warehouse with respect to the objective function, Constraints & Decision Variables.

Results: The solution is both feasible and falls within the accepted tolerance for integer solutions, indicating that the recommended manufacturing quantities can be practically implemented. The objective function, represented as "Max Z," achieves a maximum value of 29,965 units, which represents the maximum combined manufacturing quantity for all three products & the optimal values for decision variables are presented in Table III. Importantly, all constraints are met and satisfied, ensuring that the optimized solution aligns with the limitations and requirements of the manufacturing process.

Conclusions: In summary, utilizing Microsoft Excel alongside the Solver add-in and the Simplex LP algorithm, we've determined the optimal manufacturing quantities for each product type. These quantities are getting in an optimized form. Microsoft Excel's Solver add-in provides a robust platform for resolving mathematical models, empowering users to define objective functions, set constraints, and identify optimal solutions that either maximize or minimize objectives while adhering to specified constraints.

Keywords: Linear Programming Model, Warehouse's Operation, Warehouses's Space Utilization.

1. Introduction

Warehousing kept all the activities related to material handling that occur within a warehouse. [1] has defined that the typical warehouse operations involve various assignment tasks, including item allocation to various warehouse departments, space allocation, SKU zoning, picker assignment, storage location designation, storage class specification for class-based storage, determination of batch size, and order-batch assignment. These warehouse operations broadly encompass functions such as product receiving, storage, order picking, consolidation, sorting, and shipping. [2] Defines that the warehouses can be categorized into three sectors based on their operations. [3] defined as distribution warehouses, production warehouses, and contract warehouses. [4] A distribution warehouse gathers products from different suppliers (sometimes assembling them) for delivery to multiple customers. [5] Conclude in the research paper that the (LP) method furnishes leaders with the complete number of items that may be put away in a stockroom because of the various variables taken in this review. Moreover, systems influencing the utilization of warehouses at full expense are obvious. [6] Production warehouses serve as storage for raw materials, finished products & semi-finished goods within a production facility. [7] Has reviewed research paper for storage of inventory and found some scenarios of demand and supply. After that [8] invented an inventory model for time-dependent demand for the storage of deteriorating items. [9] Explained that the supply chain can be categorized into two primary segments: distribution cost and inventory value, with inventory holding cost being a key component. Opting for an environmentally sustainable supply chain is the preferred choice for companies. [10] For an in-depth exploration of warehousing systems & classification of warehouse management (WM) challenges, refer to the work of. [11] Presents a study by implementing innovative design concepts like the Flying-V & Fishbone for creating cross path within the new technical framework, warehouse's operations can reduce travel distances by 10% to 20%. [12] Additionally, with the integration of emerging technologies such as bar codes, Magnetic strips, RFID chips, or Machine vision. [13] Warehouse managers can efficiently sort and store various materials, including raw materials, works in progress & finished products. This not only conserves labor and energy but also optimizes available storage space. [14] To enhance operational efficiency, a widely employed strategy, as observed in the reviewed literature, is the practice of family grouping. [15] This involves organizing products or orders that are related or similar in closer proximity to the input/output gates or in the best-suited locations. [16] Proposed that Contract warehouses are facilities that conduct warehousing operations on behalf of one or more customers. This research will help optimize the various commodities in a warehouse.

2. Advantages

A. **Security-** Given the nature of tasks and the weight of items, warehouses inherently pose safety risks. However, when a warehouse is disorganized, these risks can escalate significantly. Prioritizing the safety of employees, inventory, tools, and machinery is paramount. An orderly warehouse not only enhances safety but also ensures the secure and protected storage of goods by assigning specific locations for them.

B. **Productiveness and Effectiveness-** An effective inventory management strategy relies on having an orderly warehouse. If your warehouse is messy or chaotic, managing your inventory becomes challenging. It's essential to store inventory in a manner that maximizes available space and maintains neatness and efficiency. This approach facilitates quick and efficient location and retrieval of inventory, ultimately expediting the order fulfillment process and ensuring customer satisfaction.

C. **Saves time & Money-** An organized warehouse enhances the precision of inventory orders. A properly maintained storage facility enables precise determination of necessary inventory levels. This not only prevents product shortages but also ensures optimal inventory levels without excess storage. Neatly showcased inventory eliminates the need for recounting, thus saving effort and ensuring accurate records.

D. **Utilizing the Available space as best possible-** Companies consistently seek additional storage space for new inventory. One major advantage of investing in a contemporary and inclusive storage system is its ability to optimize the utilization of existing warehouse space for inventory storage. Modifying an existing warehouse system proves to be simpler and more economical than acquiring an entirely new warehouse or office space.

3. Limitations

Limitations in arranging various commodities in a warehouse include:

A. **Space Constraints**- Limited warehouse space can hinder efficient commodity arrangement, resulting in overcrowding or inefficient space utilization.

B. **Compatibility Issues**- Diverse commodities with differing storage requirements, such as temperature control or stacking limitations, pose challenges in arranging them together.

C. **Fragility and Sensitivity**- Some commodities are fragile or sensitive to external factors like humidity or light, necessitating specialized storage arrangements.

D. **Inventory Management Complexity**- Managing a wide range of commodities with varying shelf lives, turnover rates, and storage needs complicates inventory management processes.

E. **Accessibility and Retrieval**- Disorganized warehouses impede commodity accessibility and retrieval, leading to order fulfillment delays and increased labor costs.

F. **Safety Hazards-** Improperly arranged commodities may cause safety hazards like falling objects or blocked emergency exits, risking structural instability.

G. **Compliance and Regulations**- Compliance with regulatory requirements or safety standards for specific storage arrangements adds complexity to warehouse management.

4. Literature Review

[17] Presents a study in which they face the problem related to the allocations & placement of commodities in the warehouse. This research depends on the concept of warehouse & storage that uses mathematical modeling for the problem of optimization, for this purpose they use the LINGO 11.0 software to solve their optimization model. [18] Presents study for the problem of inventory & facility

allocation that corporates the various sources of warehouses. The issue is inspired by a genuine circumstance that a global applied chemistry organization encountered. Several plants in this problem yield numerous goods because of the capacities & abilities of plats & multiple plants can replace a warehouse simultaneously. [19] Conduct this study to find a useful method for the product's location in a warehouse to maximize order picking's operational effectiveness by storage assignment /problem issue (SAP). [20] Presents a study in which they take a manufacturing firm of hospital products to find the maximum profit with minimum wastage at the level of production with the help of a Linear Programming Model (LPM). In this research hospital manufacturers, the different types of clothes with the aim to get the maximum profit. [21] Presents a study in which they implement the LP to identify the optimized number of products to be placed in a warehouse. [9] Presents a research supply chain management (SCM) and its various definitions. [22] Presents a study in which they focus on layout, order batching, and storage assigning strategy. [23] Conducted a study in which they formulated an LP model to optimize the production cost & developed an algorithm to find the optimized solution for large-scale warehouses. [24] Conduct a study for e-commerce warehouses in which they optimize the layout and enhance sorting efficiency. [25] Warehouse automation frequently faces difficulties throughout the design & implementation phases. In the supply chain & production, efficient warehouse & inventory management is essential. Various automation techniques & warehouse management system (WMS) architectures have been suggested throughout the literature. Ultimately, the created IoT-based solution was tested for validation in a textile industrial warehouse. [26] Distribution businesses employ sophisticated software programs known as warehouse management software systems or WMS. The WMS is a crucial component of the business & can simplify the tracking of procedures. This article explains the implementation of a smart WMS in one of Bosnia & Herzegovina's biggest distribution companies. The system enhances operation through the application of optimization algorithms & artificial intelligence. [27] Warehousing plays a crucial role in supply chains by serving as a vital connection point for material flows between suppliers and customers. [28] This paper presents the outcomes of a study conducted to assess performance levels and boost productivity in manual warehouses through the development of a Warehouse Management System (WMS) framework and cost-benefit analysis.

5. Methods

By applying a Linear Programming (LP) model, optimize the area in the palletizer warehouse.

A. Decision Variable

Y_{ij} = The number of n^{th} types of the pallet from the i^{th} type of items (for i = 1, 2, 3, …, m & n = 1, 2, 3, …, r)

B. Objective Function

The maximal amount of pallets required to meet the demand of customers for every single item type.

$$\text{Maximize } Z = C_n \sum_{i=1}^{m} Y_{in} x_{in} \text{ (for n=1, 2,…, r)} \quad (1)$$

C. Constraints

The overall no. of pallets produced by each & every kind of logistic have to be equal (=) to or less than (<) the type's daily production's availability.

$$\sum_{i=1}^{m} C_n Y_{in} \leq Q_i \qquad (for\ n = 1, 2, 3, \dots, r) \tag{2}$$

The overall quantity of pallets produced from each & every product category must be equal (=) to or less than (<) the limits of warehouse.

$$\sum_{i=1}^{m} Y_{in} \leq \sum_{i=1}^{m} A_i X_{ij} \ (for\ n = 1, 2, 3, \dots, r\ \&\ j = 1, 2, 3, \dots, t) \tag{3}$$

The quantity of pallets from each & every type that are ordered must be equal (=) to or fewer than the warehouse's limit.

$$C_n \sum_{i=1}^{m} Y_{in} \leq H \ (\ for\ n = 1, 2, 3, \dots, r) \tag{4}$$

The no. of pallets is a positive integer larger than 0 (zero). (Constraint of non-negativity)

$$Y_{in} \geq 0 (\forall\ i = 1, 2, 3, \dots, m\ \&\ n = 1, 2, 3, \dots, r) \tag{5}$$

6. Methodology

The presented linear programming model specifically addresses the efficient utilization of the ground-level storage area within a warehouse, excluding stacked storage, with a focus on palletization within the supply chain. It calculates the daily pallet requirements based on the pre-existing daily demand to maximize the efficient utilization of warehouse space. The proposed models involve linear programming methods. The quantity of pallets needed for warehouse storage can be determined in advance, ensuring the optimal utilization of storage space and meeting the demands in a manufacturing context that involves multiple products. For instance, consider the scenario presented in Table I, which illustrates the no. of pallets required to attain the specific demand quantities. Each & every type of pallet occupies the same storage area and is placed on the ground level without stacking on top of one another. Referring to Table I., the highest no. of pallets (26 pallets) is needed for a demand of 800 units, while the 650 units demand quantities require pallets (14 pallets). The highest no. of pallets (14) is needed for a demand of 540 units & the highest no. of pallets (16) is needed for a demand of 420 units.

Demand/ Area with capacity	**Types of Pallet**			
	A	**B**	**C**	**D**
	45	**40**	**35**	**25 (Manual)**
800	4	22		
650	14			
540	6	8		
420			9	3

Table I. Number of Pallet for a Particular Order

In an example scenario drawn from the auto spare parts manufacturing sector in Bhiwadi, Rajasthan, the warehouse has a maximum capacity of 30,000 units. It contains three types of products (Diff. Pin, Universal Joint Cross, Crown wheel), each having a capacity of 10,000 units. The daily demand requirements are outlined in the following Table II.

This table likely details the daily quantities needed for each product type, either by customers or for production purposes. By grasping these demand requirements, we can gauge how well the warehouse inventory matches the manufacturing operations & market's needs. The chosen commodities for this study include the Differential Pin, Universal Joint Cross, and Crown Wheel. These components are indispensable in automotive manufacturing, especially in assembling and maintaining drivetrains and differential systems. Each part plays a crucial role in ensuring vehicles operate smoothly and efficiently. Through our focus on these specific spare parts within the automotive sector, our research aims to tackle practical challenges and opportunities in manufacturing and supply chain processes. Understanding how warehouse capacity, demand requirements, and product types interact allows us to pinpoint potential areas for enhancing inventory management, production planning, and customer satisfaction in the auto spare parts industry.

Fig 1. Part Name- Diff. Pin, P. no. 2745

Fig 2. Part Name- Universal Joint Cross, P. no. 4

Fig 3. Part Name- Crown Wheel, P. no. C635

In Fig 1.the differential pin, also referred to as a pinion shaft or pinion pin, constitutes a vital component within a vehicle's drivetrain differential assembly. Its function involves providing support and securing the pinion gears within the differential housing. These pinion gears engage with the ring gear (also known as the crown wheel), thereby transferring torque from the driveshaft to the differential assembly. This mechanism facilitates the distribution of power to the axle shafts, allowing each wheel to rotate at different speeds, particularly during turns. The application of the differential pin is crucial in rear-wheel drive, all-wheel drive, and four-wheel drive vehicles, as it plays a pivotal role in transmitting torque and ensuring the smooth operation of the drivetrain.

In Fig 2. the cross pin, alternatively referred to as a spider gear shaft, plays a crucial role in differentials by facilitating torque transfer b/w side gears. Its function involves distributing rotational force evenly to both side gears, enabling wheels to rotate at varying speeds, particularly during turns. This feature is useful in preventing wheel slippage & contributes to the vehicle’s smooth operation. U.J. Cross pins are predominantly utilized in automotive drivetrains, commonly found in rear-wheel drive, all-wheel drive,& four-wheel drive vehicles.

In fig 3. crown wheel, also recognized as a ring gear, is a fundamental gear part located within a differential. Its function involves engaging with the smaller pinion gear to transfer torque from the driveshaft to the differential assembly. This process facilitates the distribution of rotational force to the axle shafts. Enabling the wheels to rotate at distinct speeds while ensuring consistent power delivery. The utilization of crown wheels is essential in automotive drivetrains, notably in rear-wheel drive, all-wheel drive,& four-wheel drive vehicles. In these systems, crown wheels play a critical role in distributing torque & managing wheel speed disparities, especially during turns & under varying road conditions.

Commodity	**Types of Order**			
	800	***650***	***540***	***420***
Diff. Pin	4	8	4	1
Universal Joint Cross	9	4	3	2
Crown Wheel	3	3	1	3

Table II. The Requirement for daily demand

7. Main Parameters

m = Total quantity of product type

H= Total quantity of order’s type

r = Overall quantity of pallet groups

P_k = The amount of pallet type in group k (where k = 1, 2, 3,…, n)

Qi = The availability of product type i’s capacity (for i =1, 2,…, n)

X(ij)= The amount of jth type of the order from the ith type of product as per to the daily demand (for i = 1, 2, 3,…, m & j= 1, 2,…, t)

A. Objective Function

$$\text{Maximize } Z = 45\sum_{i=1}^{3} Y_{i1} + 40\sum_{i=1}^{3} Y_{i2} + 35\sum_{i=1}^{3} Y_{i3} + (0.3\times 25\sum_{i=1}^{3} Y_{i3})$$

B. Constraints

For product type Diff. Pin,

$$45Y_{11} + 40Y_{12} + 35Y_{13} + 0.3\times 25Y_{13} \le 10,000$$

For product type U.J. Cross,

$$45Y_{21} + 40Y_{22} + 35Y_{23} + 0.3\times 25Y_{23} \le 10,000$$

For product type Crown wheel,

$$45Y_{31} + 40Y_{32} + 35Y_{33} + 0.3\times 25Y_{33} \le 10,000$$

For pallet type 1,

$$Y_{11} + Y_{21} + Y_{31} \le 4(X_{11} + X_{21} + X_{31}) + 14(X_{12} + X_{22} + X_{32}) + 6 (X_{13} + X_{23} + X_{33})$$

For pallet type 2,

$$Y_{12} + Y_{22} + Y_{32} \le 8(X_{11} + X_{21} + X_{31}) + 22(X_{13} + X_{23} + X_{33})$$

For pallet type 3,

$$Y_{13} + Y_{23} + Y_{33} \le 9(X_{14} + X_{24} + X_{34})$$

C. Decision variable for Lower Bound

If 650 unit's orders were placed then lower bound for the 1 type of pallet.

$Y_{i1} \ge 14$ Where i = 1, 2, 3

If 540 unit's orders were placed then lower bound for the 1 type of pallet.

$Y_{i1} \ge 6$ Where i = 1, 2, 3

If 800 unit's orders were placed then lower bound for the 1 type of pallet.

$Y_{i1} \ge 4$ Where i = 1, 2, 3

If 800 unit's orders were place then lower bound for the 2 type of pallet

$Y_{i2} \ge 22$ Where i = 1, 2, 3

If 540 unit's orders were place then lower bound for the 2 type of pallet

$Y_{i2} \ge 8$ Where i = 1, 2, 3

If 420 unit's orders were place then lower bound for the 3 type of pallet

$Y_{i3} \ge 9$ Where i = 1, 2, 3

Decision variables, i = 1, 2, 3 & n = 1, 2, 3, 4

$$Y_{in} = Integer$$

Non-negativity constraint: $Y_{ij} \geq 0$ & $Q_i \geq 0$

8. Results

In the analyzed example scenario, the focus was to optimize manufacturing quantities for three different types of products. The solution is both feasible and falls within the accepted tolerance for integer solutions, indicating that the recommended manufacturing quantities can be practically implemented. The objective function, represented as "Max Z," achieves a maximum value of 29,965 units, which represents the maximum combined manufacturing quantity for all three products & the optimal values for decision variables are presented in Table III. Importantly, all constraints are met and satisfied, ensuring that the optimized solution aligns with the limitations and requirements of the manufacturing process.

X_{in}	***Type of Pallet***		
Commodity	45(1)	40(2)	35(3)
Diff. Pin	0	250	0
Universal Joint Cross	100	54	78
Crown Wheel	221	0	0

Table III. Optimized Solution BY LP

Based on the optimized values of the decision variables, it is determined that the manufacturing quantities for each product type should be as follows: 10,000 units for Diff. Pin, 10,000 units for the product Universal Joint Cross, and 9965 units for the product Crown Wheel. The software employed for this optimization is Microsoft Excel, specifically using the Solver add-in and the Simplex LP algorithm within the Solver Engine. Microsoft Excel Solver add-in serves as a robust tool for optimizing & resolving mathematical models. It empowers users to define an objective function, establish constraints & identify the optimal solution that either maximizes or minimizes the objective while adhering to the specified constraints.

The Solver Engine utilizes the Simplex LP algorithm, a popular technique for solving linear programming problems, to iteratively search for the best solution. This algorithm systematically navigates through feasible solutions within the specified constraints, gradually moving towards the optimal solution by exploring the boundaries of the feasible region.

By utilizing Microsoft Excel along with the Solver add-in and the Simplex LP algorithm, the optimization process becomes efficient in determining the most suitable manufacturing quantities for each product type. This enables businesses to make informed decisions based on data analysis, optimize production workflows, utilize resources effectively, and fulfill market demand while ensuring operational practicality and effectiveness.

9. Discussion

The scenario we've explored focuses on optimizing storage quantities for three different types of commodities. Our analysis confirms that the proposed solution not only falls within acceptable bounds for integer solutions but also demonstrates practical implementation capabilities. By utilizing the objective function labeled "Maximize Z," we achieve the highest feasible combined storage quantity for all three commodities. These optimal quantities are carefully elucidated to emphasize the most effective values for the decision variables. Throughout our analysis, we've diligently ensured that all constraints are met and satisfied. This thorough approach ensures that our optimized solution aligns seamlessly with the limitations and requirements of the manufacturing process. Table III provides a detailed breakdown of the optimized values for decision variables, offering clarity on the recommended quantities for each product. This comprehensive breakdown reinforces the practicality and efficiency of our proposed solution. In summary, our investigation emphasizes the importance of optimizing storage quantities to not only meet but exceed industry standards. By meticulously considering constraints, maximizing objective functions, and offering clear recommendations, we aim to facilitate informed decision-making and enhance operational efficiency within the manufacturing process.

10. Conclusion

In summary, utilizing Microsoft Excel alongside the Solver add-in and the Simplex LP algorithm, we've determined the optimal manufacturing quantities for each product type. These quantities are getting in an optimized form. Microsoft Excel's Solver add-in provides a robust platform for resolving mathematical models, empowering users to define objective functions, set constraints, and identify optimal solutions that either maximize or minimize objectives while adhering to specified constraints.

11. Future Scope

In mathematics, the future of efficient techniques for arranging commodities in warehouses entails progress in optimization algorithms, especially in linear programming and combinatorial optimization. Advanced mathematical models may be created to reduce storage space usage while enhancing accessibility and retrieval efficiency. This encompasses the exploration of sophisticated graph theory algorithms for optimizing warehouse layout designs and inventory routing algorithms for dynamic inventory management. Furthermore, developments in predictive analytics and machine learning algorithms can forecast demand patterns and optimize inventory allocation strategies, ensuring warehouses operate efficiently while meeting customer needs.

Refrences

[1] Manzini, R., Accorsi, R., Pattitoni, L. and Regattieri, A., 2011. A supporting decisions platform for the design and optimization of a storage industrial system. Efficient Decision Support Systems-Practice and Challenges in Multidisciplinary Domains, 2, p.64.

[2] Geraldes, C.A., Carvalho, M.S. and Pereira, G., 2012. Warehouse Design and Product Assignment and Allocation: a mathematical programming model.

[3] Van den Berg, J.P. and Zijm, W.H., 1999. Models for warehouse management: Classification and examples. International journal of production economics, 59(1-3), pp.519-528.

[4] Hompel, M. and Schmidt, T., 2006. Warehouse management: automation and organisation of warehouse and order picking systems. Springer Science & Business Media.

[5] Gupta, C., Kumar, V. and Gola, K.K., 2022, December. Implementation Analysis for the Applications of Warehouse Model Under Linear Integer Problems. In International Conference on Intelligent Systems Design and Applications (pp. 239-247). Cham: Springer Nature Switzerland.

[6] Muppani, V. R., & Adil, G. K. (2008). Efficient formation of storage classes for warehouse storage location assignment: a simulated annealing approach. Omega, 36(4), 609-618.

[7] Saxena, A.K., 2021, December. Review on EOQ Models for Instanteneous and Non-Instanteneous Deteriorating Items. In 2021 10th International Conference on System Modeling & Advancement in Research Trends (SMART) (pp. 312-315). IEEE.

[8] Saxena, A.K., 2022, December. An EOQ Model for Deteriorating Items with Time Dependent Demand. In 2022 11th International Conference on System Modeling & Advancement in Research Trends (SMART) (pp. 926-930). IEEE.

[9] Gupta, C., Kumar, V. and Kumar, K., 2022, December. A Study on the Applications of Supply Chain Management. In 2022 11th International Conference on System Modeling & Advancement in Research Trends (SMART) (pp. 737-741). IEEE.

[10] Ballesteros-Riveros, F.A., Arango-Serna, M.D., Adarme-Jaimes, W. and Zapata-Cortes, J.A., 2019. Storage allocation optimization model in a Colombian company. Dyna, 86(209), pp.255-260.

[11] Karásek, J., 2013. An overview of warehouse optimization. International journal of advances in telecommunications, electrotechnics, signals and systems, 2(3), pp.111-117.

[12] Geraldes, C.A., Carvalho, M.S. and Pereira, G., 2012. Warehouse Design and Product Assignment and Allocation: a mathematical programming model.

[13] Perera, D., Fernando, A. and Mirando, U., 2021. Warehouse Space Optimization Using a Linear Programming Model.

[14] Kumar, P., Saxena, A., Gupta, G.K. and Kumar, K., 2022, December. Duality of Graph and Its Application in Electric Circuit. In 2022 11th International Conference on System Modeling & Advancement in Research Trends (SMART) (pp. 1561-1563). IEEE.

[15] Perera, D., Mirando, U. and Fernando, A., 2022. WAREHOUSE SPACE OPTIMIZATION USING LINEAR PROGRAMMING MODEL AND GOAL PROGRAMMING MODEL.

[16] Pohl, L.M., Meller, R.D. and Gue, K.R., 2009. An analysis of dual-command operations in common warehouse designs. Transportation Research Part E: Logistics and Transportation Review, 45(3), pp.367-379.

[17] Khannan, M.S.A., Nafisah, L. and Palupi, D.L., 2018, March. Design for warehouse with product flow type allocation using linear programming: A case study in a textile industry. In IOP conference series: Materials science and engineering (Vol. 319, No. 1, p. 012013). IOP Publishing.

[18] Yao, Z., Lee, L.H., Jaruphongsa, W., Tan, V. and Hui, C.F., 2010. Multi-source facility location–allocation and inventory problem. European Journal of Operational Research, 207(2), pp.750-762.

[19] Pan, J.C.H., Shih, P.H., Wu, M.H. and Lin, J.H., 2015. A storage assignment heuristic method based on genetic algorithm for a pick-and-pass warehousing system. Computers & Industrial Engineering, 81, pp.1-13.

[20] Goel, D., Shah, D.K. and Somani, D., 2018. A linear programming approach to maximize profit and minimize wastage in a hospital products manufacturing firm- global services ltd.

[21] Manoharan, S., Stilling, D., Kabir, G. and Sarker, S., 2022. Implementation of Linear Programming and Decision-Making Model for the Improvement of Warehouse Utilization. Applied System Innovation, 5(2), p.33.
Manoharan, S., Stilling, D., Kabir, G. and Sarker, S., 2022. Implementation of Linear Programming and Decision-Making Model for the Improvement of Warehouse Utilization. Applied System Innovation, 5(2), p.33.

[22] De Koster, R., Le-Duc, T. and Roodbergen, K.J., 2007. Design and control of warehouse order picking: A literature review. European journal of operational research, 182(2), pp.481-501.

[23] Zhang, G., Shang, X., Alawneh, F., Yang, Y. and Nishi, T., 2021. Integrated production planning and warehouse storage assignment problem: An IoT assisted case. International Journal of Production Economics, 234, p.108058.

[24] Hu, X. and Chuang, Y.F., 2023. E-commerce warehouse layout optimization: systematic layout planning using a genetic algorithm. Electronic Commerce Research, 23(1), pp.97-114.

[25] Khan, Muhammad Gufran, Noor Ul Huda, and Uzair Khaleeq Uz Zaman. "Smart warehouse management system: Architecture, real-time implementation and prototype design." Machines 10.2 (2022): 150.

[26] Žunić, E., Delalić, S., Hodžić, K., Beširević, A., & Hindija, H. (2018, November). Smart warehouse management system concept with implementation. In 2018 14th Symposium on Neural Networks and Applications (NEUREL) (pp. 1-5). IEEE

[27] Ramaa, A., Subramanya, K. N., & Rangaswamy, T. M. (2012). Impact of warehouse management system in a supply chain. International Journal of Computer Applications, 54(1).

[28] Gupta, C., Kumar, V., & Kumar, K. (2023, December). A Linear Programming Approach to Optimize the Storage Capacity. In 2023 12th International Conference on System Modeling & Advancement in Research Trends (SMART) (pp. 508-511). IEEE.