Journal of Intelligent Management Decision
https://www.acadlore.com/journals/JIMD

Optimizing Warehouse Capacity in Industrial Manufacturing Through Centralised Storage System Integration

Žarko Jovanović[1], Željko Stević[1*], Stojan Simić[2]

[1] Faculty of Transport and Traffic Engineering Doboj, University of East Sarajevo, 74000 Doboj, Bosnia and Herzegovina
[2] Faculty of Mechanical Engineering, University of East Sarajevo, 71123 East Sarajevo, Bosnia and Herzegovina

[*] Correspondence: Željko Stević (zeljko.stevic@sf.ues.rs.ba)

Received: 04-01-2025 **Revised:** 05-20-2025 **Accepted:** 05-26-2025

Citation: Ž. Jovanović, Ž. Stević, and S. Simić, "Optimizing warehouse capacity in industrial manufacturing through centralised storage system integration," *J. Intell Manag. Decis.*, vol. 4, no. 2, pp. 137–147, 2025. https://doi.org/10.56578/jimd040204.

Abstract: To enhance cost-efficiency and streamline logistics operations in industrial manufacturing, centralised warehouse systems have increasingly been adopted as a strategic alternative to decentralised storage structures. In this study, the storage framework of a lubricating oil production facility has been examined to assess the operational implications of decentralised warehousing currently in use. It has been identified that the existing system incurs excessive operational costs, prolongs handling times, and demands a disproportionately high labour force, thereby constraining the overall efficiency of the supply chain. In response to projected increases in production output, the feasibility of constructing a centralised, gravity-fed warehouse equipped with automated and robotic technologies for the handling of palletised goods has been investigated. This proposed facility would be strategically integrated with the product packaging unit to form a unified logistical hub within the manufacturing site. A comprehensive analysis was conducted to determine the optimal location for the central warehouse, with key criteria including material flow, space availability, connectivity to production lines, and scalability. The results indicate that the implementation of a centralised automated storage and retrieval system (AS/RS) would significantly improve warehouse throughput, reduce operational expenditures, and align closely with long-term production expansion plans. Additionally, the integration of advanced storage technologies is expected to enhance inventory visibility, minimise human error, and support real-time production coordination. It is concluded that the establishment of a central warehouse facility, functioning as a core node in the internal logistics network, is essential for achieving sustainable operational efficiency and future-proofing the lubricating oil manufacturing process.

Keywords: Centralised warehouse; Industrial logistics; Storage optimisation; Operational efficiency; Automation; Lubricating oil production; Cost reduction

1 Introduction

In manufacturing plants, the organization of logistics processes plays a significant role. Some of the most important logistics processes include the receipt, storage and dispatch of goods to the market. In the past, warehouse systems were relatively static, with the storage of goods being the dominant activity. Today, however, it is a highly dynamic system where goods circulate at a high intensity, causing a change in the management concept. Many plants operate with a decentralized organization of goods storage. Goods are stored in warehouses located away from production facilities and spread across multiple locations. A decentralized warehouse organization is inefficient in terms of time spent transporting goods by internal transport vehicles, storage efficiency, dispatch efficiency, the number of personnel serving the warehouses, manual labor involved in warehousing, labor costs, fuel consumption, and the maintenance costs of internal transport vehicles. To reduce storage costs and increase operational efficiency, centralized warehouses are most commonly used in manufacturing plants. By centralizing the warehouse, the following goals are achieved: inventory optimization, reduction of fixed and variable costs, improvement of distribution, increase of productivity, better utilization of space and reduction of damage to goods.

This paper examines the centralization of storage systems in a lubricating oil manufacturing plant, taking into account current and future storage capacity requirements. The general objective is to identify potential areas within the storage and internal transport systems that can improve efficiency and to address the question of how to rationalize the goods management process. In the lubricating oil manufacturing plant, which currently operates with a decentralized storage system, a project of decomposition of the existing logistics system is being considered with the aim of storing all produced goods in a central warehouse from which they would be dispatched to the market. By switching to a centralized storage system – which entails storing goods at an optimal location relative to the production facilities and making full use of internal transport – significant improvements would be achieved in terms of internal logistics within the plant. Decomposing the existing logistics system in the lubricating oil manufacturing plant would significantly contribute to reducing operating costs and increasing the efficiency of warehouse operations.

Conceptually, the paper is organized into five logically interconnected sections. The introductory considerations outline the initial facts and the motivation for addressing the centralization of the warehouse as a highly complex issue through a specific example. Section 2 analyzes previous research on the centralization of storage systems and the solutions implemented in the process. Section 3 presents the research methods and empirical formulas used to demonstrate the advantages of centralized versus decentralized storage systems in manufacturing plants. Section 4 provides specific research conducted in a manufacturing plant with a decentralized storage system. The research includes an analysis of the current warehouse layout, the rationale for establishing a centralized warehouse, and the benefits of storing goods at a single location instead of multiple locations. Section 5 analyzes the results of the conducted research in comparison with findings from other studies in the field.

2 Previous Research

Warehousing is one of the fundamental processes in every manufacturing company. In order to meet market demands, a manufacturing company must have the required quantities and types of products, which means it must have a well-organized storage system. Storage-related costs are relatively high, making their reduction crucial for increasing the company's profit. The closer the warehouse location is to the optimal point, the lower the costs of transporting goods and the greater the operational efficiency of the company. Manufacturing companies conduct efficiency and cost-effectiveness analyses of their logistics processes based on the organization of the storage system, i.e., whether the storage system is centralized or decentralized. The main difference between these two systems is that, in centralized warehousing, goods are stored in one large warehouse, while in decentralized warehousing, goods are stored in several smaller warehouses located at multiple different locations. Warehouse centralization is becoming an increasingly important topic in logistics and supply chain management. Studies have shown that this approach can offer numerous benefits, including reduced operating costs, improved inventory control, and enhanced distribution efficiency. Supporting this topic, Graungaard Pedersen et al. [1] analyzed, in their research, the key factors influencing the choice between the centralization and decentralization of warehouse locations from investors' perspective, while Stević et al. [2], using a specific example from industrial production, decomposed an existing decentralized storage system, conducted a detailed analysis of all processes, and proposed an efficient centralized warehousing solution. Analyzing storage systems in industrial production, Mulalić et al. [3] demonstrated that centralizing warehouses optimizes resources, improves inventory and stock control, and rationalizes the use of internal transport, leading to cost reduction and increased operational efficiency. The study by Milewski [4] showed that warehouse centralization can significantly reduce inventory variability and enable better control over inventory. This research highlights that centralization is particularly beneficial in industries with high demand variability, where it is necessary to quickly adjust inventory to market needs. According to a case study on the rationalization of logistics processes in industrial production by Taş [5], the application of the Logistics 4.0 concept – which implies full automation of warehouse logistics management – leads to reduced operating costs, focusing on sustainability parameters such as workforce, warehouse area, and optimized use of transport vehicles. Gunasekaran et al. [6], in their case study, stated that proper organization of warehouse operations can reduce unnecessary operations by more than 20%, leading to increased efficiency of rationalizing resource consumption. When determining storage requirements and storage capacities during the design of a centralized warehouse, a critical factor is the proper routing of goods through the central storage system, taking into account constraints such as distance and the time required for a pallet to complete the full cycle – receiving, storage and dispatch. Elbert et al. [7] analyzed the influence of the human factor on efficient routing, while Roodbergen et al. [8] contributed to the field by developing an algorithm for automatic pallet routing schemes, taking into account a large number of parameters that influenced the storage process. In their study, Weidinger et al. [9] considered the possibilities of developing an adaptive model for filling warehouse capacities in fully automated warehouses using metaheuristic programming methods. Additionally, Hou et al. [10], in their research, developed a heuristic algorithm for warehouse capacity allocation, which, based on inventory and warehouse data, performed consolidation using a two-phase warehouse reallocation method aimed at increasing the number of available storage locations. Van Gils et al. [11] contributed to the understanding of the functioning of centralized automated warehouses by using a full-factorial ANOVA analysis to demonstrate the relationship between storage, order grouping, storage capacity zoning, and inventory movement routing within storage capacities. Yetkin et al. [12, 13], in their studies, analyzed the necessary resources, key performance indicators, and energy efficiency of automated storage systems that used shuttle systems for receiving and dispatching pallets in centralized storage systems. Azadeh et al. [14] identified the development directions of a new category of automated and robotic goods handling systems, storage and retrieval systems based on shuttle systems, as well as robotic mobile systems for order processing and preparation. To demonstrate the advantages of a centralized storage system over a traditional decentralized one, Milewski [15] developed his own efficiency strategy model of a centralized storage system. Through 1,300 simulations, he came to an optimal centralization solution with wide applicability, ranging from agricultural production and industrial manufacturing to retail stores and wholesale distribution centers. Regarding inventory optimization, Fleischmann [16] stated in his research that the centralization of storage systems has a great impact on inventory optimization, particularly in cases where customers are supplied directly from the warehouse in full truckloads, with no additional pallet picking involved.

Ganbold et al. [17] examined process optimization and workforce reallocation strategies when centralizing warehouse systems, stating that the implementation of modern robotic solutions in centralized warehouse systems reduces needs for manual labor. This reduction requires a planned strategy for deploying the current workforce, hiring new employees, and dealing with technological redundancies that arise due to technical and technological process advancements. Garcia et al. [18] analyzed the security aspects of warehouse centralization. Their research reveals that although centralization can increase efficiency, it also carries the risk of significant losses in the event of incidents, which requires improvements in safety measures and protocols. These risks must be taken into account when designing centralized warehouses.

The relevance of warehouse system management and the establishment of a foundation for their automation are becoming increasingly evident, particularly in developing countries. In logistics systems, which are flexible and dynamic, optimization is a key factor, and it is achieved through proper management of their own processes and their automation, as confirmed by numerous studies addressing automation issues [19–22].

3 Research Methods

In collecting data for this research, a methodology of empirical measurements and calculations was used to provide accurate and relevant data suitable for further systematization and processing. This approach allows for a precise and thorough analysis of empirical data, ensuring that the research results are credible and relevant for further application and interpretation.

The first step is to determine the maximum storage capacity of the current decentralized storage system with six separate storage facilities. Measurements and analysis were conducted, and based on that, the total maximum capacity was obtained. The maximum storage capacity prior to centralization represents the sum of the maximum storage capacities of all six facilities:

$$\sum S_{max} = \sum S_{ob1} + \sum S_{ob2} + \sum S_{ob3} + \sum S_{ob4} + \sum S_{ob5} + \sum S_{ob6} \tag{1}$$

For each storage facility, coefficients (k) have been defined, representing the ratio of the maximum capacity of each individual facility to the total maximum capacity:

$$k_u = k_1 + k_2 + k_3 + k_4 + k_5 + k_6 = 1 \tag{2}$$

where,

$$k_1 = \frac{\sum S_{ob1}}{\sum S_{max}},\ k_2 = \frac{\sum S_{ob2}}{\sum S_{max}},\ k_3 = \frac{\sum S_{ob3}}{\sum S_{max}},\ k_4 = \frac{\sum S_{ob4}}{\sum S_{max}},\ k_5 = \frac{\sum S_{ob5}}{\sum S_{max}},\ k_6 = \frac{\sum S_{ob6}}{\sum S_{max}}.$$

In order to adequately determine the time and resources spent on handling packaged goods, measurements were taken of both the distance and time required to transport a pallet from the packaging location to the storage location. Based on the average value for each facility, distance and time parameters have been defined, and they will be used for further interpretation.

For each facility, the cumulative distance traveled by the forklift to transport the pallets with goods from the packaging location to the storage location during the observed time interval has been defined:

$$Ps_{cum} = (d_{s1} \cdot\ n_{s1}) + (d_{s2} \cdot\ n_{s2}) + (d_{s3} \cdot\ n_{s3}) + (d_{s4} \cdot\ n_{s4}) + (d_{s5} \cdot\ n_{s5}) + (d_{s6} \cdot\ n_{s6}) \tag{3}$$

where,

- Ps_{cum} – the cumulative forklift transport work during the storage of goods for all six facilities in the observed time interval,

- d_{s1} to d_{s6} – the measured average values of distances for each of the six observed facilities,
- n_{s1} to n_{s6} – the number of pallets of goods transported to each of the six observed facilities during storage.

Based on the determined average time required to transport a pallet to a specified location, a mathematical expression has been defined to determine the total time required for a forklift to transport and store all pallets during the observed time interval:

$$Ts_{cum} = (t_{s1} \cdot n_{s1}) + (t_{s2} \cdot n_{s2}) + (t_{s3} \cdot n_{s3}) + (t_{s4} \cdot n_{s4}) + (t_{s5} \cdot n_{s5}) + (t_{s6} \cdot n_{s6}) \tag{4}$$

where,
- Ts_{cum} – cumulative time spent transporting pallets of goods to the warehouse in the observed time interval,
- t_{s1} to t_{s6} – measured mean values of time spent for each of the six observed facilities.

Similarly to the storage process, an analysis of the loading process of goods from all six observed facilities was also conducted to adequately determine the time and resources spent on handling packaged goods. Measurements of both the distance and time required to transport a pallet from the storage location to the loading location of the transport vehicle were conducted. Based on the average values for each facility, distance and time parameters have been defined, and they will be used for further interpretation of the obtained results and their impact on the decision to centralize the storage capacities.

For each facility, the cumulative distance traveled by the forklift to transport the pallets from the storage location to the loading location during the observed time interval has been defined:

$$Pl_{cum} = (d_{l1} \cdot n_{l1}) + (d_{l2} \cdot n_{l2}) + (d_{l3} \cdot n_{l3}) + (d_{l4} \cdot n_{l4}) + (d_{l5} \cdot n_{l5}) + (d_{l6} \cdot n_{l6}) \tag{5}$$

where,
- Pl_{cum} – cumulative forklift transport work during the dispatch and loading of goods in the observed time interval,
- d_{l1} to d_{l6} – measured mean values of the distance from the storage location to the loading location for each of the six observed facilities,
- n_{l1} to n_{l6} – number of pallets transported during the loading of goods for each of the six observed facilities.

Based on the determined average time required to transport a pallet to a designated loading location, a mathematical expression for the total time required for the forklift to transport and load all pallets during the observed time interval has been defined:

$$Tl_{cum} = (t_{l1} \cdot n_{l1}) + (t_{l2} \cdot n_{l2}) + (t_{l3} \cdot n_{l3}) + (t_{l4} \cdot n_{l4}) + (t_{l5} \cdot n_{l5}) + (t_{l6} \cdot n_{l6}) \tag{6}$$

where,
- Tl_{cum} – cumulative time spent on transport for loading pallets in the observed time interval,
- t_{l1} to t_{l6} – measured mean values of the time required for transport and loading from each of the six observed facilities.

The engagement of machinery for the transport of packaged pallets with goods to the location of loading the goods into the vehicle was analyzed. The total distance traveled required to transport and load all pallets during the observed time interval was defined.

Additionally, a detailed analysis of inventory movement was performed through the analytical processing of data obtained from the accounting software used as a tool for inventory management, receiving, dispatch and invoicing of goods.

4 Structure of Warehouse Centralization Research

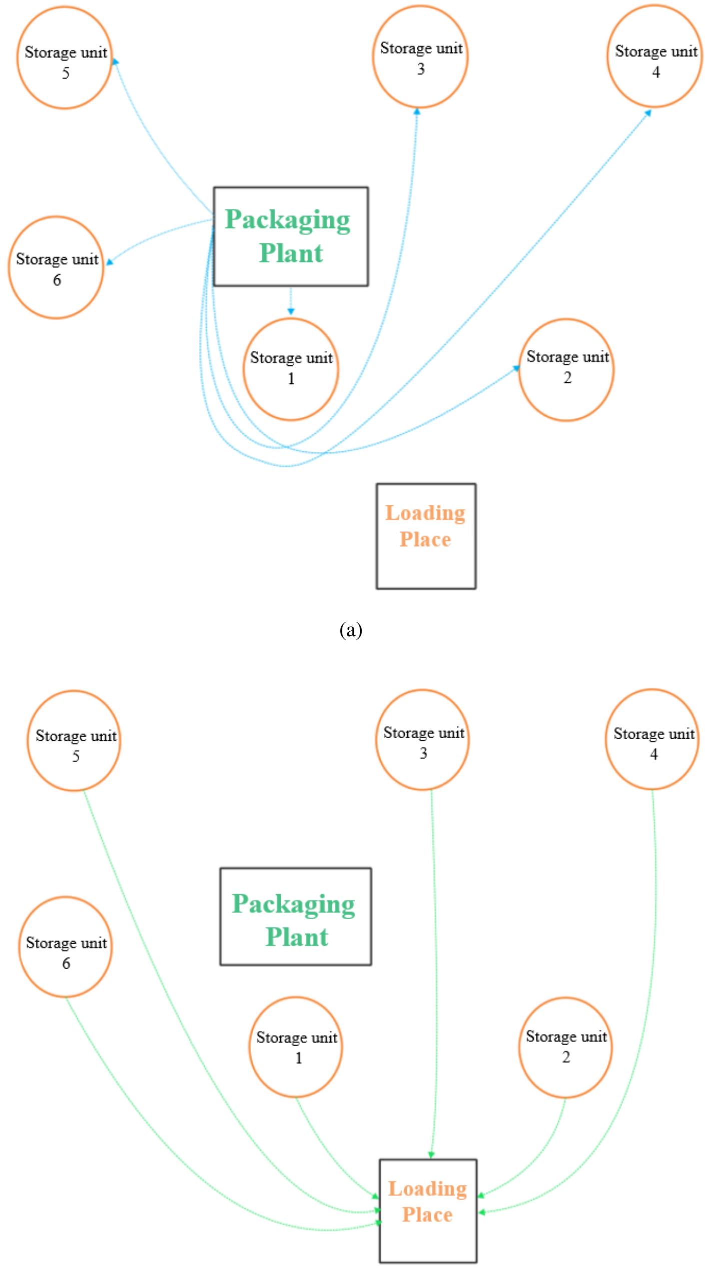
In relation to the facility where goods are packaged, the warehouse layout is not logistically favorable. The layout is also unfavorable in terms of loading goods into transport vehicles. Table 1 shows the distance between the warehouse and the packaging facility, as well as the locations where goods are loaded into transport vehicles.

Figure 1 shows the current layout of storage capacities as well as forklift trajectories during the storage and loading of goods into transport vehicles. The transport of goods from the packaging and storage facility to six separate warehouse locations is shown in subgraph (a) of Figure 1. Subgraph (b) of Figure 1 shows the forklift trajectories during the loading of goods from the six warehouses into transport vehicles.

According to Eq. (1), the maximum storage capacity prior to centralization represents the sum of the maximum storage capacities of all six facilities, totaling 6,816 pallet spaces.

Table 1. Distance of the warehouse from the packaging facility and the loading location for transport vehicles

Warehouse Label	Distance of the Warehouse from the Packaging Facility (m)	Distance of the Warehouse from the Vehicle Loading Location (m)
Facility 1	10	90
Facility 2	108	73
Facility 3	290	260
Facility 4	420	390
Facility 5	310	300
Facility 6	10	120



(b)

Figure 1. Diagram of warehouse capacity distribution and forklift movement trajectories: a) forklift trajectory during storage of goods, b) forklift trajectory during loading of goods into transport vehicles

For each storage facility, coefficients (k) were calculated, representing the ratio of the total maximum capacity Smax to the maximum capacity of each individual facility. In this case, the values of the individual coefficients are as follows:

$$\begin{aligned} k_1 &= \frac{1340}{6816} = 0.20, \quad k_2 = \frac{870}{6816} = 0.13, \quad k_3 = \frac{1872}{6816} = 0.26 \\ k_4 &= \frac{400}{6816} = 0.06, \quad k_5 = \frac{1560}{6816} = 0.13, \quad k_6 = \frac{864}{6816} = 0.13 \end{aligned} \tag{7}$$

The total coefficient (k_u) equals 1, which represents the coefficient of the total maximum storage capacity:

$$k_u = 0.20 + 0.13 + 0.26 + 0.06 + 0.23 + 0.13 = 1 \tag{8}$$

For the purposes of the analysis, data on the quantity of goods packaged and dispatched during the period from 2021 to 2023 were used (Table 2).

Table 2. Quantity of goods produced and dispatched in the period from 2021 to 2023

Observed Period (year)			**2021**	**2022**	**2023**
Packaged	Facilities 1-4	Mass (t)	5,835	6,503	6,533
		EUR pallet (units)	14,589	16,260	16,335
Dispatched		Mass (t)	6,772	6,173	6,448
		EUR pallet (units)	16,931	15,433	16,122
Packaged	Facilities 5-6	Mass (t)	4,472	5,389	5,668
		CP3 pallet (units)	5,591	6,737	7,086
Dispatched		Mass (t)	4,628	5,782	5,221
		CP3 pallet (units)	5,786	7,228	6,527

Using the formulas for calculating the total distance traveled (Eq. (3)) and the total time spent (Eq. (4)) for pallet transport during warehousing, the following results are obtained:

- The total cumulative distance traveled ($P_{s_{cum}}$) for the observed period 2021-2023 is 27,961 km,
- The total cumulative time ($T_{s_{cum}}$) for the observed period 2021-2023 is 2,633 h and 49 min.

By inserting the measured values into the formulas for calculating the total distance traveled (Eq. (5)) and the total time spent (Eq. (6)) for transport during dispatch and loading of pallets, the following results are obtained:

- The total cumulative distance traveled (Pl_{cum}) for the observed period 2021-2023 is 23,731 km,
- The total cumulative time (Tl_{cum}) for the observed period 2021-2023 is 2,218 h and 49 min.

The obtained values for the distance traveled and the cumulative time will be used to calculate the costs generated during the observed period, which are directly related to the transport of pallets from the production location to the warehouse and the dispatch of goods from the warehouse to the transport vehicle.

The total warehousing costs (transportation of goods from the production location to the warehouse) and loading costs (transportation of goods from the warehouse to the loading vehicle) include operating costs, technical maintenance costs of internal transport vehicles and workforce costs. These are calculated using the following formula:

$$\sum C = C_{op} + C_{mt} + C_{wf} \tag{9}$$

where,

C_{op} – operating costs (diesel fuel consumption),

C_{mt} – technical maintenance costs for internal transport vehicles (scheduled maintenance, repairs, replacement of consumables, tires),

C_{wf} – workforce costs (net hourly wage for forklift drivers).

Operating costs (C_{mt}) were calculated as follows:

- Average diesel fuel consumption per working hour – 4 liters,
- Average diesel fuel price during the observed period – €1.50/liter,
- Total operating time – 2,634 hours for warehousing operations and 2,219 hours for goods dispatch.

Technical maintenance costs for internal transport vehicles (C_{mt}) were calculated as follows:

- Annual maintenance costs per forklift – €2,000,

- Observed maintenance period – 3 years.
Workforce costs (C_{wf}) were calculated as follows:
- Gross hourly wage for a forklift driver – €4,
- Total working time – 2,634 hours for warehousing operations and 2,219 hours for goods dispatch.

Table 3 shows the total costs for the current method of transportation, storage organization, and goods dispatch for the period 2021-2023.

Table 3. Total costs of storage and dispatch of goods for the period 2021-2023

Cost Type	Unit Cost (€)	Quantity	Costs (€)
Operating costs - fuel (C_{op})	29,100	4 forklifts	116,400
Vehicle technical maintenance costs (C_{mt})	2,000	8 forklifts	16,000
Workforce costs (C_{wf})	19,400	14 workers	271,600
Total costs			404,000

From Table 3, it can be seen that the total costs of storage and goods dispatch for the observed period 2021-2023 amount to €404,000.

The lubricating oil manufacturing plant, where the warehousing processes have been analyzed, has consistently experienced growth in production and sales, which also requires the reorganization of internal logistics within the plant.

The analyses conducted have shown that the existing storage capacities will not be sufficient when the annual production volume reaches 15,000 tonnes of goods in small packaging, i.e., goods that are palletized. It is evident that the current system of organizing the storage of goods is irrational from several aspects. It is inefficient in terms of the duration of storage operations, operating costs, technical maintenance costs for internal transport vehicles, and labor costs. In addition, the existing storage facilities have certain structural deficiencies.

In order to reduce the duration of storage operations and the costs associated with the storage of goods, one of the most acceptable solutions is the construction of a central warehouse for palletized goods. The central gravity-fed warehouse should be designed in such a way that robotic technology can be fully applied for managing goods within the warehouse.

The selection of location for the construction of the central gravity-fed warehouse is a complex issue and requires considering multiple aspects. The location of the central gravity-fed warehouse has been selected so that the newly built warehouse facility will be directly connected to the facility where the goods are palletized. When designing the central warehouse, the following factors should be taken into account:
- The number of product assortments (types of products and number of packages in different packaging),
- Production volume,
- Inventory levels in the warehouse (minimum, maximum and optimal inventory levels), and
- Coefficient of the inventory turnover in the warehouse.

Figure 2 shows the location of the central gravity-fed warehouse.

Figure 2. Locations of the central gravity-fed warehouse

The selected location for the construction of the central gravity-fed warehouse would be favorable for the following reasons:

- Existing buildings would not need to be removed;
- The topography of the land where the central gravity-fed warehouse would be built is relatively suitable, as the elevation difference (level) between the ground level and the warehouse floor could be adjusted, which would facilitate the construction of loading ramps for trucks and other delivery vehicles;
- The existing road infrastructure within the company's industrial zone could be fully utilized;
- The space where the central gravity-fed warehouse would be constructed is of a suitable size for the warehouse dimensions and meets the requirements related to logistical infrastructure needed for vehicles arriving to load goods;
- The location is also suitable from the aspect of connecting the warehouse to existing energy, electrical and utility installations.

The main goals achieved by the construction of the central gravity-fed warehouse in the lubricating oil manufacturing plant are:

- All goods will be stored in one warehouse;
- The capacity of the central warehouse will match the production volume and inventory turnover coefficient for different product assortments;
- Reduction of logistics costs;
- Minimization of manual labor;
- Minimization of the subjective influence of workers during the receiving, storage and dispatch of goods;
- Goods dispatch using the FIFO system;
- Minimization of potential errors during the dispatch of goods;
- Increased flexibility in the warehouse during the dispatch of goods;
- Automation and robotization of certain operations in the warehouse.

In addition to the above, the construction of the central gravity-fed warehouse follows these trends: timely response of production to market demands, continued growth in the sales of finished products, and increased consumer satisfaction.

Figure 3 illustrates the schematic layout of pallet racks in the flow-through gravity-fed warehouse.

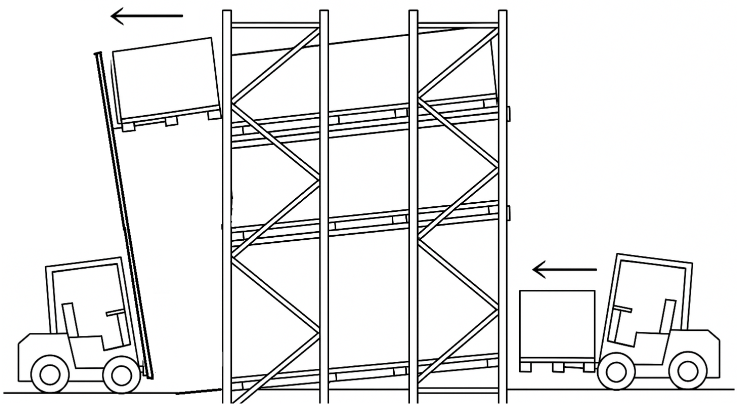


Figure 3. Schematic layout of racks in the flow-through gravity-fed warehouse

The area of the central gravity-fed warehouse is 3,565 m^2. This is actually a high-rack gravity-fed warehouse with a height up to 12 meters, featuring seven levels of racking with a total capacity of 4,700 t or 7,470 pallet spaces. In addition to the racks, the warehouse should also include offices for warehouse staff and charging stations for electrically powered forklifts and pallet jacks. The total capacity, i.e., the number of pallet spaces in the central gravity-fed warehouse, was determined based on the following: the planned increase in production in the upcoming period, the expansion of the product assortments, and the coefficient of the inventory turnover in the warehouse.

The newly constructed central gravity-fed warehouse would fully support the development plans of the lubricating oil manufacturing plant in the upcoming period. Its capacity would be sufficient to meet the demands associated with increasing lubricating oil production to 30,000 t/year – a target expected to be achieved within the next 10 years. Compared to the current warehouse organization, the construction of the central gravity-fed warehouse would not only expand storage capacity but also reduce operating costs, technical maintenance costs for internal transport vehicles, and labor costs. When analyzing storage and distribution expenses over a three-year period, based on an annual production and distribution volume of 15,000 t/year – the estimated costs are as follows: operating costs - fuel (C_{op}) would amount to 0 euros, vehicle technical maintenance costs (C_{mt}) would be approximately 8,000 euros and workforce costs (C_{wf}) would be approximately 135,800 euros. It is evident that the construction of the central gravity-fed warehouse would reduce warehousing operation costs by approximately 260,000 euros over a three-year period, while also enabling an increase in production and sales of 3,000 to 4,000 tonnes annually.

Figure 4 shows the basic dimensions of the central gravity-fed warehouse, as well as the layout of the racks in the warehouse.

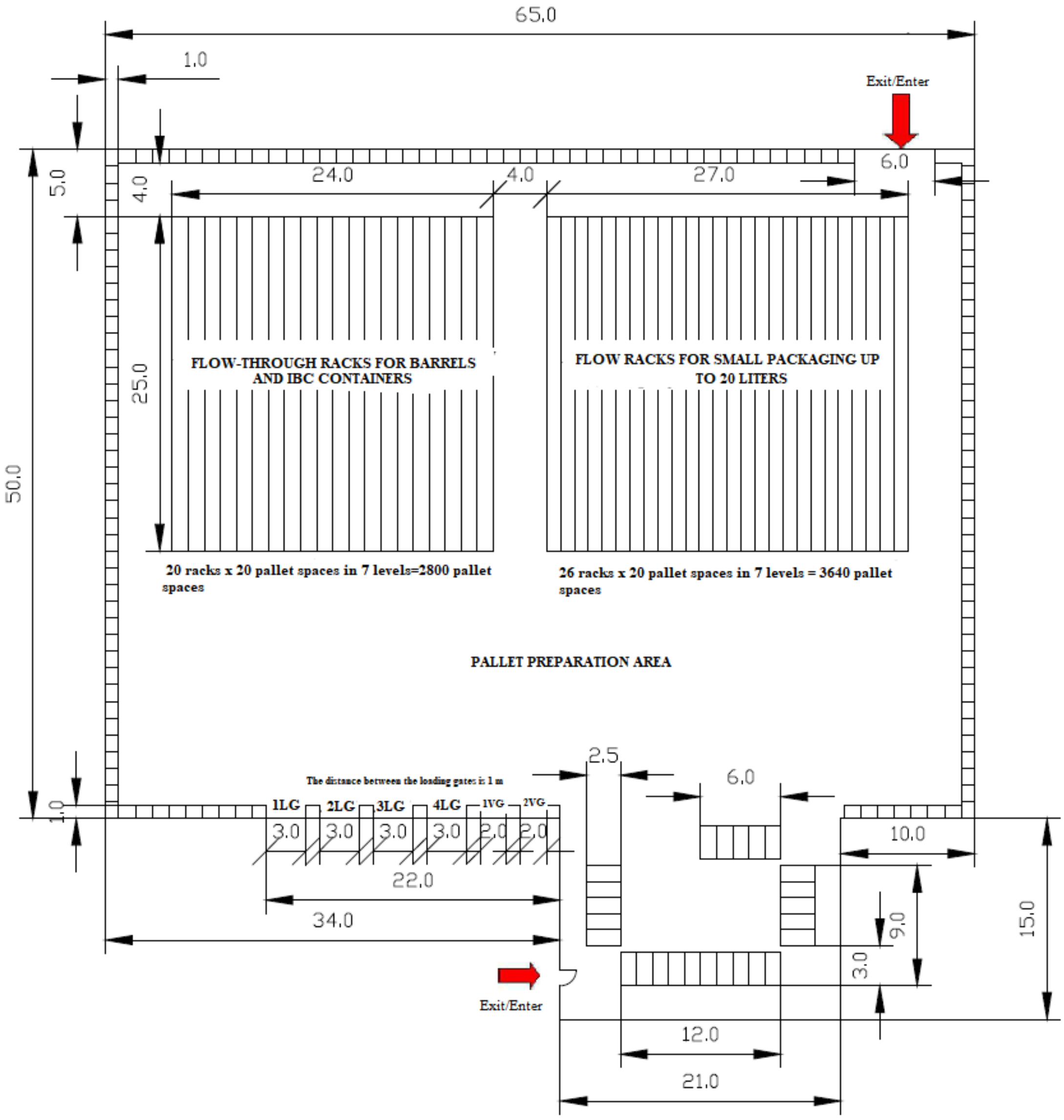


Figure 4. Dimensions of the central gravity-fed warehouse

The central gravity-fed warehouse should be designed as an energy-efficient facility. Given that the warehouse covers an area of 3,565 m^2 and is oriented towards the south, this provides a good foundation for the construction of a photovoltaic power plant on its roof. The installed capacity of the photovoltaic power plant would be approximately 350 kW. The generated electricity would be used for warehouse lighting and for charging the batteries of internal transport vehicles used within the warehouse. In addition to energy efficiency, the construction of the central gravity-fed warehouse would also yield environmental benefits, manifested in reduced environmental pollution from exhaust gases emitted by internal transport vehicles.

5 Conclusions

The storage system, as a part of logistics, is almost indispensable in all segments of the supply chain, especially for companies engaged in manufacturing activities. This paper analyzes the current warehouse organization for goods produced in a lubricating oil plant. The results of the analysis show that the increase in the production volume of lubricating oils has not been accompanied by the development of storage infrastructure. The conducted research has shown that the current warehouse organization is irrational and inefficient. The irrationality and inefficiency are reflected in the lengthy duration of warehouse operations, high operating costs, and a large number of personnel involved, which contribute to high labor costs and low process efficiency within the warehouse.

A detailed analysis of the logistics flows within the lubricating oil plant – taking into account various aspects and monitoring all processes from production, packaging, and storage to the distribution of goods to the market – identified the most logical location for the central gravity-fed warehouse. It has been determined that the newly constructed warehouse will be directly connected to the facility where the packaging of finished products takes place. The construction of the central gravity-fed warehouse achieves the following:

- The storage capacities would meet the requirements in line with the growth of production and sales in the upcoming period;
- Manual labor during warehouse operations would be reduced;
- Flexibility in storage and goods dispatch would be increased;
- Operating costs and internal transport vehicle maintenance costs would be significantly reduced;
- Positive energy efficiency and environmental effects would be achieved.

The conducted research contributes to the continuous improvement of inventory management and goods distribution processes, ensuring the long-term efficiency and sustainability of production and logistics operations in the lubricating oil manufacturing plant. The study analyzed the current decentralized storage system, and proposals for its improvement were developed through the application of appropriate empirical methods and a review of relevant literature in the field. In order to obtain the most reliable research results, it would be desirable to create a physical model of the proposed central warehouse, which was not feasible under the current research conditions. Future research on the optimization of internal logistics in the lubricating oil plant should include the development of systems for automation and robotization of processes in the central warehouse, such as receiving, storage and distribution of goods to the market.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

References

[1] S. Graungaard Pedersen, F. Zachariassen, and J. Stentoft Arlbjørn, “Centralisation vs decentralisation of warehousing,” *J. Small Bus. Enterp. Dev.*, vol. 19, no. 2, pp. 352–369, 2012. https://doi.org/10.1108/14626001211223946

[2] Ž. Stević, E. Mulalić, Z. Božičković, S. Vesković, and I. Đalić, “Economic analysis of the project of warehouse centralization in the paper production company,” *Serb. J. Manag.*, vol. 13, no. 1, pp. 47–62, 2018. https://doi.org/10.5937/sjm13-13608

[3] E. Mulalić, Ž. Stević, Z. Božičković, M. Vasiljević, and S. Sremac, “Decomposition and centralization of warehouse systems in order to rationalize material flows,” in *International Conference Transport and Logistics-TIL, Niš, Serbia*, 2017, pp. 83–90.

[4] D. Milewski, “The combined decision problem: “Pull” vs. “push” and the degree of centralization of warehousing in the field of physical distribution with a special focus on the Polish market,” *Appl. Sci.*, vol. 15, no. 7, p. 3970, 2025. https://doi.org/10.3390/app15073970

[5] U. Taş, “Case study of intralogistics in the framework of Logistics 4.0,” *Int. J. Automot. Sci. Technol.*, vol. 7, no. 1, pp. 18–24, 2023. https://doi.org/10.30939/ijastech..1215381

[6] A. Gunasekaran, H. Marri, and F. Menci, “Improving the effectiveness of warehousing operations: A case study,” *Ind. Manag. Data Syst.*, vol. 99, no. 8, pp. 328–339, 1999. https://doi.org/10.1108/02635579910291975

[7] R. M. Elbert, T. Franzke, C. H. Glock, and E. H. Grosse, “The effects of human behavior on the efficiency of routing policies in order picking: The case of route deviations,” *Comput. Ind. Eng.*, vol. 111, pp. 537–551, 2017. https://doi.org/10.1016/j.cie.2016.11.033

[8] K. J. Roodbergen, G. P. Sharp, and I. F. Vis, “Designing the layout structure of manual order picking areas in warehouses,” *IIE Trans.*, vol. 40, no. 11, pp. 1032–1045, 2008. https://doi.org/10.1080/07408170802167639

[9] F. Weidinger, N. Boysen, and D. Briskorn, “Storage assignment with rack-moving mobile robots in KIVA warehouses,” *Transp. Sci.*, vol. 52, no. 6, pp. 1479–1495, 2018. https://doi.org/10.1287/trsc.2018.0826

[10] J.-L. Hou, Y.-J. Wu, and Y.-J. Yang, “A model for storage arrangement and re-allocation for storage management operations,” *Int. J. Comput. Integr. Manuf.*, vol. 23, no. 4, pp. 369–390, 2010. https://doi.org/10.1080/09511921003642154

[11] T. van Gils, K. Ramaekers, K. Braekers, B. Depaire, and A. Caris, "Increasing order picking efficiency by integrating storage, batching, zone picking, and routing policy decisions," *Int. J. Prod. Econ.*, vol. 197, pp. 243–261, 2018. https://doi.org/10.1016/j.ijpe.2017.11.021

[12] B. Y. Ekren and A. Akpunar, "An open queuing network-based tool for performance estimations in a shuttle-based storage and retrieval system," *Appl. Math. Model.*, vol. 89, pp. 1678–1695, 2021. https://doi.org/10.1016/j.apm.2020.07.055

[13] B. Y. Ekren, A. Akpunar, Z. Sari, and T. Lerher, "A tool for time, variance and energy related performance estimations in a shuttle-based storage and retrieval system," *Appl. Math. Model.*, vol. 63, pp. 109–127, 2018. https://doi.org/10.1016/j.apm.2018.06.037

[14] K. Azadeh, R. De Koster, and D. Roy, "Robotized and automated warehouse systems: Review and recent developments," *Transp. Sci.*, vol. 53, no. 4, pp. 917–945, 2019. https://doi.org/10.1287/trsc.2018.0873

[15] D. Milewski, "Total costs of centralized and decentralized inventory strategies—Including external costs," *Sustainability*, vol. 12, no. 22, p. 9346, 2020. https://doi.org/10.3390/su12229346

[16] B. Fleischmann, "The impact of the number of parallel warehouses on total inventory," *OR Spectr.*, vol. 38, no. 4, pp. 899–920, 2016. https://doi.org/10.1007/s00291-016-0442-2

[17] O. Ganbold, K. Kundu, H. Li, and W. Zhang, "A simulation-based optimization method for warehouse worker assignment," *Algorithms*, vol. 13, no. 12, p. 326, 2020. https://doi.org/10.3390/a13120326

[18] A. García, Y. Seok Chang, and R. Valverde, "Impact of new identification and tracking technologies on a distribution center," *Comput. Ind. Eng.*, vol. 51, no. 3, pp. 542–552, 2006. https://doi.org/10.1016/j.cie.2006.08.013

[19] L. Custodio and R. Machado, "Flexible automated warehouse: A literature review and an innovative framework," *Int. J. Adv. Manuf. Technol.*, vol. 106, no. 1-2, pp. 533–558, 2019. https://doi.org/10.1007/s00170-019-04588-z

[20] E. O. Sodiya, U. J. Umoga, O. O. Amoo, and A. Atadoga, "AI-driven warehouse automation: A comprehensive review of systems," *GSC Adv. Res. Rev.*, vol. 18, no. 2, pp. 272–282, 2024. https://doi.org/10.30574/gscarr.2024.18.2.0063

[21] V. Simic, S. Dabic-Miletic, E. B. Tirkolaee, Ž. Stević, A. Ala, and A. Amirteimoori, "Neutrosophic LOPCOW-ARAS model for prioritizing industry 4.0-based material handling technologies in smart and sustainable warehouse management systems," *Appl. Soft Comput.*, vol. 143, p. 110400, 2023. https://doi.org/10.1016/j.asoc.2023.110400

[22] M. Hompel and T. Schmidt, *Warehouse Management: Automation and Organisation of Warehouse and Order Picking Systems*. Springer Science & Business Media, 2006.