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RESEARCH AND IMPROVEMENT OF THE FLOW OF RAW MATERIALS AND SEMI-FINISHED PRODUCTS IN THE PRODUCTION PROCESS

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Purpose: The following paper will outline the results of the analysis and the proposed solutions for improving the flow of raw materials and semi-finished products in the production process of a selected company. The emphasis will be on the project to eliminate time losses.
Design/methodology/approach: The primary research objectives were accomplished through empirical verification of the impact of the implementation of a new warehouse management system (WMS) on the efficiency of the raw materials and semi-finished products picking process. The study was based on the chronometry method, which involves the precise measurement of the time required to perform specific activities.
Findings: The study demonstrated that investing in technological solutions (WMS) and reorganising the workspace is an effective method of eliminating time losses, which is the most valuable resource in an era of growing competition. It is evident that inefficiency in the management of raw materials has a detrimental effect on the timely progression of production.
Practical implications: The WMS system has been shown to eliminate bottlenecks in the process of picking raw materials and semi-finished products, which is crucial for production efficiency. The reduction in picking time by 55% had a direct impact on the optimisation of the flow of raw materials and semi-finished products, which consequently resulted in the elimination of time losses throughout the production process. The study confirmed that investing in technology and reorganising the workspace is an effective way to optimise the most valuable resource – time. The project was concluded successfully within the specified budget and timeframe, thereby enabling the company to acquire practical experience in project management.
Originality/value: The paper provides empirical evidence that the strategic integration of Lean Logistics concepts with advanced IT systems is effective. The originality of the study lies in the development and implementation of a proprietary WMS that is perfectly tailored to the needs of the company.
The paper is intended for a readership comprising managers, logistics specialists and students. It provides a practical case study that demonstrates the efficacy of a methodical, project-based approach in effecting enduring changes in production processes.
Keywords: production flows, warehouse management, project management, WMS.
Category of the paper: Research paper, case study.

1. Introduction

In the contemporary business environment, manufacturing companies are confronted with significant challenges in their pursuit of maintaining a competitive advantage in terms of operational and logistical efficiency. A crucial aspect that influences these challenges is the assurance of process continuity. In this context, the foundation for maintaining the fluidity and synchronisation of the entire production cycle is the optimal flow of materials and semi-finished products. Inefficiencies in this area frequently result in substantial temporal losses, which in turn lead to production delays. In the contemporary market environment, it is imperative to achieve precise synchronisation between material delivery and processing to minimise downtime and maximise productivity. In response to the aforementioned challenges, companies are increasingly seeking innovative solutions, including advanced warehouse management systems (WMS), with a view to streamlining critical processes and eliminating identified bottlenecks. Despite numerous publications on Lean Management and Lean Logistics, there is still a lack of empirical research that systematically analyzes the impact of implementing a dedicated warehouse management system (WMS) on the efficiency of the material picking process in single-unit and small-batch production conditions (Ohno, 1988; Baudin, 2005; Serafin et al., 2014).

The objective of the present paper is twofold: firstly, to present research findings on the process of picking items in a materials and semi-finished products warehouse; secondly, to describe this process; and thirdly, to empirically verify the impact of implementing a new warehouse management system (WMS) on its efficiency. It was hypothesized that the implementation of the WMS system and the reorganization of the warehouse would significantly reduce picking times, improving the flow of raw materials and semi-finished products in production. This objective was achieved through a dual observation process employing chronometry, conducted prior to and following the implementation of the alterations. This facilitated an analysis of the impact of the WMS implementation on the reduction of time losses in the picking process. Consequently, it was possible to assess the validity of the improvements introduced.

2. Literature review

The Lean Management philosophy, which has been derived from the Toyota Production System (TPS), has gained recognition as a comprehensive approach to business management. The primary goal of this philosophy is to maximise value for the customer by eliminating all forms of waste (Ohno, 1988). In recent years, Lean principles and tools have been adapted for application in various functional areas of organisations, including logistics. This development has resulted in the expansion of the concept to encompass the notion of Lean Logistics (Antczak, Puchała, 2014). The implementation of this concept in a particular setting, such as a warehouse, has necessitated the exploration of contemporary methodologies and solutions aimed at eradicating losses that are characterised as Muda. This approach is of particular importance in the field of production logistics, the primary function of which is to manage the flow of materials – from raw materials through to finished products – in a manner that ensures continuity of processes and minimises unnecessary inventories (Dębski, 1993). In the domain of production logistics management, the objective is to deliver materials in a manner that eradicates waste and only when they are required (Baudin, 2005). This is achieved through the implementation of the lean concept. In view of the heterogeneity of production processes, the philosophy of lean logistics must be practised in a manner that is tailored to the needs and capabilities of companies.

The above considerations clearly demonstrate that the logistics system occupies an equivalent strategic position to the production system (Cybulska et al., 2014). This interdependence fundamentally necessitates their holistic integration and management in a process synergy model. In the context of contemporary supply chains, the absence of a coherent connection between these systems results in the inefficient use of resources and diminished operational efficiency, consequently impacting the competitiveness of the company.

The element that binds both systems together is the flow of materials, which creates the dynamics of transformation and value, turning raw materials into useful products, while organising time, space and human cooperation in the pursuit of satisfying needs. This encompasses not only the physical movement of raw materials or products, but also the broader logistical processes involved in ensuring the seamless flow of materials and goods. This is a method that encompasses the management, planning and control of all phases of material movement. These phases begin at the moment of acquisition and continue through successive stages of processing in production, culminating in the delivery of the finished product to the customer (Szymonik , 2015).

In the context of logistics and production, efficient material flow requires coordination of activities aimed at eliminating all bottlenecks, unnecessary downtime and excessive inventories (Krawczyk, 2000). The objective is to ensure the availability of materials in accordance with their necessity, in the required quantities, with minimal delays and costs. Internet-enabled information systems play a pivotal role in ensuring this, as they facilitate the real-time processing and provision of data, in addition to enabling intelligent flow management. The advent of dynamic technological development and widespread access to advanced digital solutions has engendered a paradigm shift in corporate practices. Organizations now have the capability to adapt and implement systems that effectively eliminate waste, reduce costs and significantly increase operational flexibility (Serafin, 2014). This technological revolution in material flow management constitutes the foundation for the establishment of resilient and competitive supply chains in the era of Industry 4.0. Further research and optimisation in this domain represent a key challenge for contemporary production logistics theory and practice.

3. Description of the research method used

In the course of the research, conducted on the basis of SOR-DREW S.A. as a case study, an endeavour was made to empirically validate the hypothesis that the implementation of alterations in the functioning of the materials and semi-finished products warehouse, with a particular emphasis on the implementation of a new warehouse management system (WMS), would result in a substantial reduction in time losses in the process of picking raw materials and semi-finished products. In view of the aforementioned points, the preliminary stage of the research comprised a comparative analysis of traditional methods of picking details cut from sheet metal using a laser cutter against the newly developed concept. The chronometry employed in this study was defined as a technique for recording and measuring the time required to perform specific activities or entire processes. The data obtained was utilised to measure the time consumption of picking and to ascertain the extent to which the WMS contributed to the reduction of working time. The objective of the study was twofold: firstly, to assess the validity of the improvement that had been introduced, and secondly, to consider the implications of this improvement.

The subject of the study comprised two steel construction projects, characterised by twin similarity. The selection of two projects was determined by the particular nature of the company's production, which is characterised by single-unit and small-batch production. This inherent characteristic of the production process renders it impossible to study a larger number of objects at the same time. The selection criteria encompassed the dimensions of the structures, the number of details, and the similar thicknesses of the sheets from which the details were cut. It was hypothesised that such a comparison would provide reliable and representative results. Both projects were distinguished by their unique nomenclature, individual six-digit main order numbers, and technical drawings. The characteristics of both structures are included in Table 1.

Table 1.
Characteristics of the analysed designs

	First project – picked manually	Second project – picked by the WMS system
Name	P1-020637	P2-020637
Drawing number	E50115-B3247-B259	E50115-B3247-B271
ZG number	418442	418479

Source: Own work.

A model employee in the position of warehouse worker was selected for both measurements in order to eliminate the influence of human factors on the results. The duration of the search was measured with a stopwatch, commencing from the moment the search for an item was initiated and concluding when the item was located. The data was recorded in real time and entered into a prepared spreadsheet. The completion of the first project (manual) was carried out in the manner practised prior to the implementation of the changes. The components were arranged in a random manner on pallets and shelves, and the employee was required to utilise a technical drawing in order to identify the necessary items independently. The total duration of the preparatory and concluding phases of the process was 20 minutes and 23 seconds. The results obtained are presented in Table 2.

Table 2.
Results of the first project picking

Picking **[418442]**			
[B259] P1-020637			
Order number	**Drawing number**	**Description**	**Measurement time [min]**
418445	E50115-B3247-B259 (bl.≠10 S235)	item 4 - 4 pcs item 1001 - 6 pcs item 1002 - 2 pcs item 1003 - 2 pcs item 1006 - 24 pcs	8:40
418446	E50115-B3247-B259 (bl.≠15 S235 UT)	item 1004 - 2 pcs	2:15
		item 1005 - 2 pcs	2:00
418448	E50115-B3247-B259 (bl.≠30 S235 UT)	item 6 - 3 pcs.	2:13
418450	E50115-B3247-B259 (bl.≠8 S235)	item 1008 - 3 pcs	5:15
		TOTAL	**20:23**

Source: Own work.

The second measurement study incorporated a novel approach to the receipt and dispatch of goods from the warehouse. Subsequent to the laser engraving process, the components were annotated with stickers, expedited to pallets, entered into the system, and subsequently allocated to shelves. The foreman was tasked with generating a picking list that delineated the locations, which was subsequently provided to the employee along with an auxiliary technical drawing. This drawing initiated the process of taking measurements. The total duration of the order preparation and completion process was 9 minutes and 5 seconds. The results obtained are presented in Table 3.

Table 3.
Results of the second project picking

Picking **[418479]**			
[B271] P2-020637			
Order number	**Drawing number**	**Description**	**Measurement time [min]**
418482	E50115-B3247-B271 (bl.≠10 S235)	item 4 - 4 pcs item 1001 - 6 pcs item 1002 - 4 pcs item 1005 - 24 pcs	2:50
418483	E50115-B3247-B271 (bl.≠15 S235 UT)	item 1003 - 2 pcs	1:40
418484	E50115-B3247-B271 (bl.≠20 S235 UT)	item 1004 - 2 pcs	1:23

418486	E50115-B3247-B271 (bl.≠25 S235 UT)	item 6 - 3 pcs	1:23
418495	E50115-B3247-B271 (bl.≠8 S235)	item 1007 - 3 pcs	1:49
		TOTAL	**9:05**

Source: Own work.

The actual time measurements obtained for the technological operation – namely, the picking of main orders – yielded two summary results reflecting the execution of the process. Each of the tests was compiled, and the distributions of the analysed items were presented graphically in the form of two chronometric series, presented in Figure 1 and Figure 2, respectively. As illustrated in the graphs, the vertical axis denotes the time, measured in minutes, required to complete the items presented on the horizontal axis.

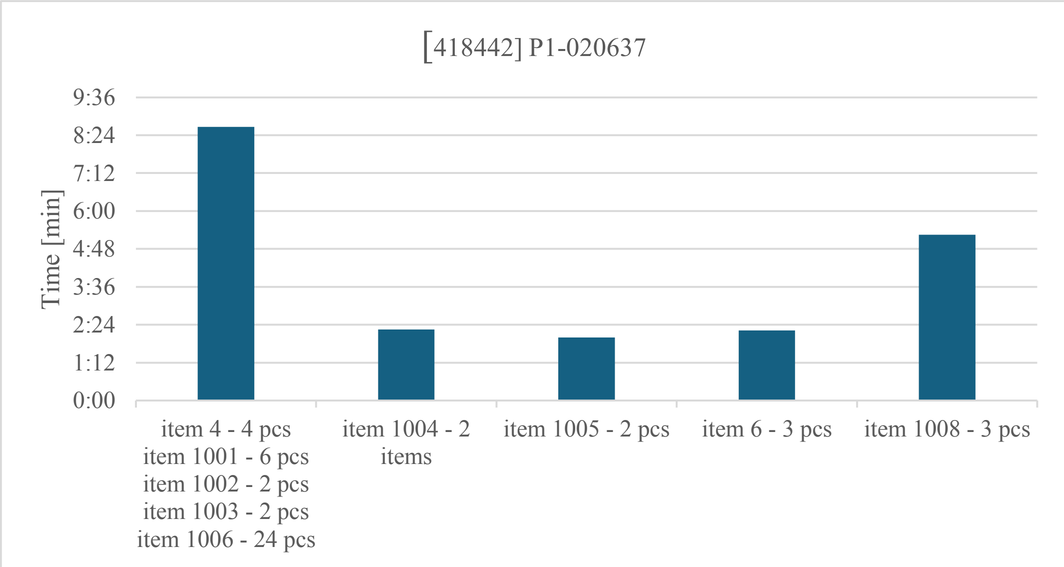


Figure 1. Chronometric series of the first design.

Source: Own work.

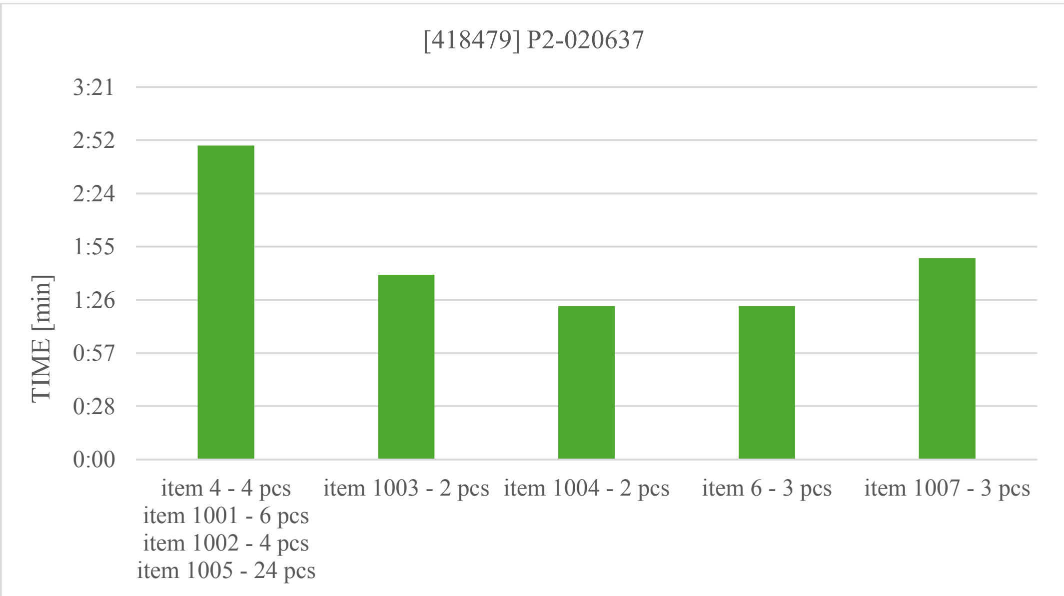
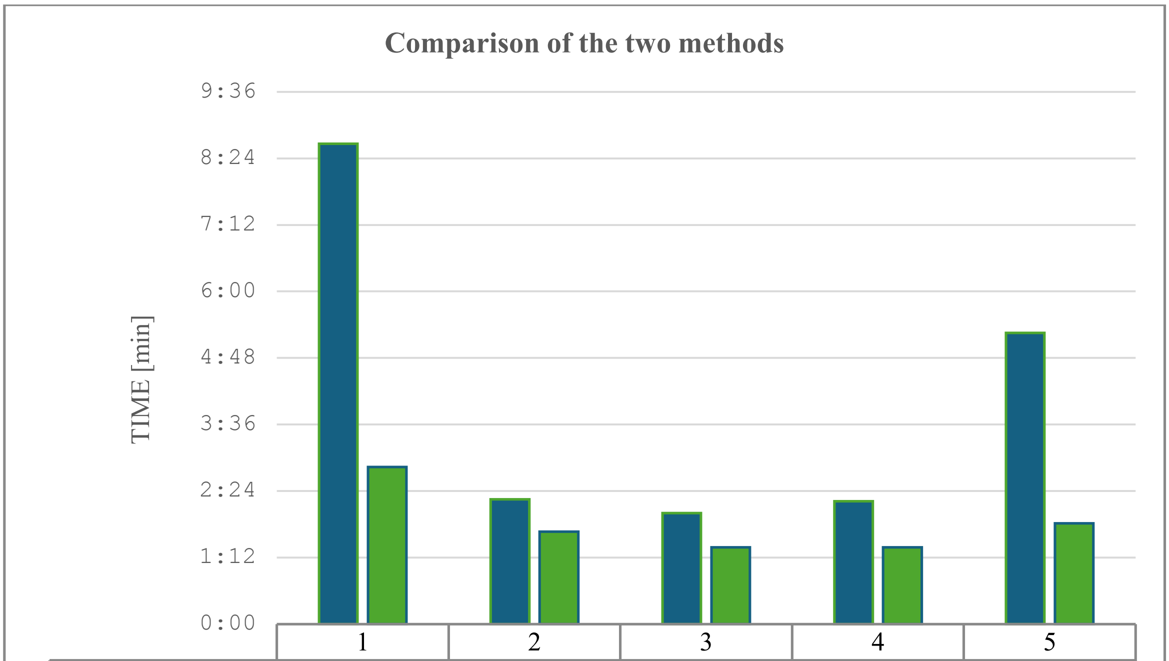


Figure 2. Chronometric series of the second design.

Source: Own work.

In order to visualise the differences between the two completion methods, the results have been compiled in a single chart, shown in Figure 3.



	1	2	3	4	5
Picking [418442]	8:40	2:15	2:00	2:13	5:15
Picking [418479]	2:50	1:40	1:23	1:23	1:49

Figure 3. Chronometric series of both projects.

Source: Own work.

This comparison evidently demonstrates that each of the five items exhibited a reduced picking time in the novel system. The most significant reduction in duration was observed for the initial item, with a decrease from 8 minutes and 40 seconds to 2 minutes and 50 seconds. For the remaining items (2, 3, 4, 5), the WMS system also resulted in lower measurement outcomes. Furthermore, in the new system, these items were characterised not only by shorter times, but also by lower deviations. As demonstrated in the initial chart, the irregularity of the time differences serves to further corroborate the observations that were made during the course of the measurements.

In summary, the introduction of the Warehouse Management System (WMS) will result in a substantial enhancement in work efficiency, owing to a reduction in the time required to complete orders. The implementation of this system is expected to contribute to the equalisation and stabilisation of the process, thereby facilitating the optimisation of logistics pathways and enhancing the efficiency of material identification procedures. The time study provided unequivocal evidence in support of the hypothesis that optimising the picking processes is a valid objective.

4. Implementation project to eliminate time losses

A comprehensive improvement plan was developed on the basis of a detailed time study which yielded highly positive results. This study clearly confirmed the improvement of the picking process after the pilot implementation of the warehouse management system (WMS). The focus of the project was twofold, with activities concentrated on the reorganisation of the physical warehouse infrastructure and the further implementation of the integrated WMS IT system.

The reorganisation of the warehouse comprised the establishment of a permanent zone for semi-finished products, the relocation of pallets for the purpose of tidying, and the installation of new racks. Storage locations were meticulously catalogued using a dual-axis system, incorporating both chronological and alphabetical organisation, with the utilisation of barcodes on labels to facilitate efficient identification.

The internal WMS system, which is based on an Excel spreadsheet with macros, was designed as a low-cost, intuitive solution that is tailored to the specific needs of the company. The system automates the registration, tracking and completion of orders, and dynamically updates stock levels. In order to enhance automation, the format of detail labels was standardised by introducing a barcode for the main order (MO) number and a QR code for the drawing number, both of which were linked to the customer's order. The implementation of an industrial tablet, equipped with an integrated code reader and Excel software, was instrumental in optimising warehouse operations. The system interface was divided into three distinct functional areas: entry, retrieval and preview of details. During the training programme, the employees were provided with comprehensive operating instructions.

The company has successfully optimised its production processes by eliminating the identified bottleneck in the area of component picking. A pivotal component of this transformation was the development and implementation of an innovative, proprietary warehouse management system (WMS) that is tailored to the unique characteristics of metal product manufacturing. The implementation of the WMS, in conjunction with the restructuring of the storage area and the redesign of the warehouse layout, yielded quantifiable advantages. A time study confirmed a significant reduction in the time needed to pick parts – by as much as 55%. The implementation of integrated measures, encompassing organisational modifications and the integration of information technology, has been demonstrated to engender substantial enhancements in the efficiency of the movement of raw materials and semi-finished products. This, in turn, has resulted in the eradication of temporal losses.

Following a comprehensive review of the study's findings, it was determined that implementing changes was imperative. To this end, a project was initiated with the primary objective of enhancing the efficiency of the process involved in the picking of raw materials and semi-finished products utilised in the production cycle. The project's primary goal was to achieve a substantial reduction in the time required for this stage of the production process. The implementation of theoretical assumptions using a project management approach has been demonstrated to be a practical way to introduce changes in manufacturing or service processes (Karbownik, 2017).

The project was formalised and documented using a project charter, which clearly defined its deadlines, scope, main objective and sub-objectives. This pivotal step was instrumental in facilitating the authorisation of the project, thereby conferring upon the manager the prerogative to appoint a dedicated project team comprising the following members: The roles encompass Production Director, Technologist, IT Specialist, Warehouse Worker and External Stakeholder.

The work breakdown structure (WBS), which is a hierarchical decomposition of the entire scope of the project, was divided into five main phases, within which detailed tasks were defined. The implementation of all tasks was approached via a waterfall methodology, emphasising the sequential implementation of project stages and strict adherence to a predetermined schedule. The schedule identified three milestones that were of particular significance in terms of the progression of the project:

- "Management decision" – the milestone marking the start of the project.
- "Completion of system design" – a milestone defining the completion of the design phase and allowing for the implementation of the next phases.
- "Project completion" – the milestone ending the project.

In order to facilitate precise visualisation of the schedule and comprehensive illustration of the structure of dependencies between tasks, the project defined a critical path (Critical Path Method - CPM). A graphical representation of this analysis is illustrated in Figure 4. This path is defined as a sequence of tasks that directly determine the minimum time required to complete the project (Musioł-Urbańczyk et al., 2021). The implementation of tasks on the critical path must be executed in a timely manner to ensure the overall success of the project. Any delay in this process will result in a delay to the entire project. The critical path of the project was presented in graphical form as an AoN (activity on node) network diagram. The EMPM (Extended Metra Potentional Method) technique was utilised in order to ascertain the aforementioned objective, a process which enabled the consideration of complex dependencies and time constraints. It is evident that tasks which are on the critical path are distinguished by the use of orange colouring.

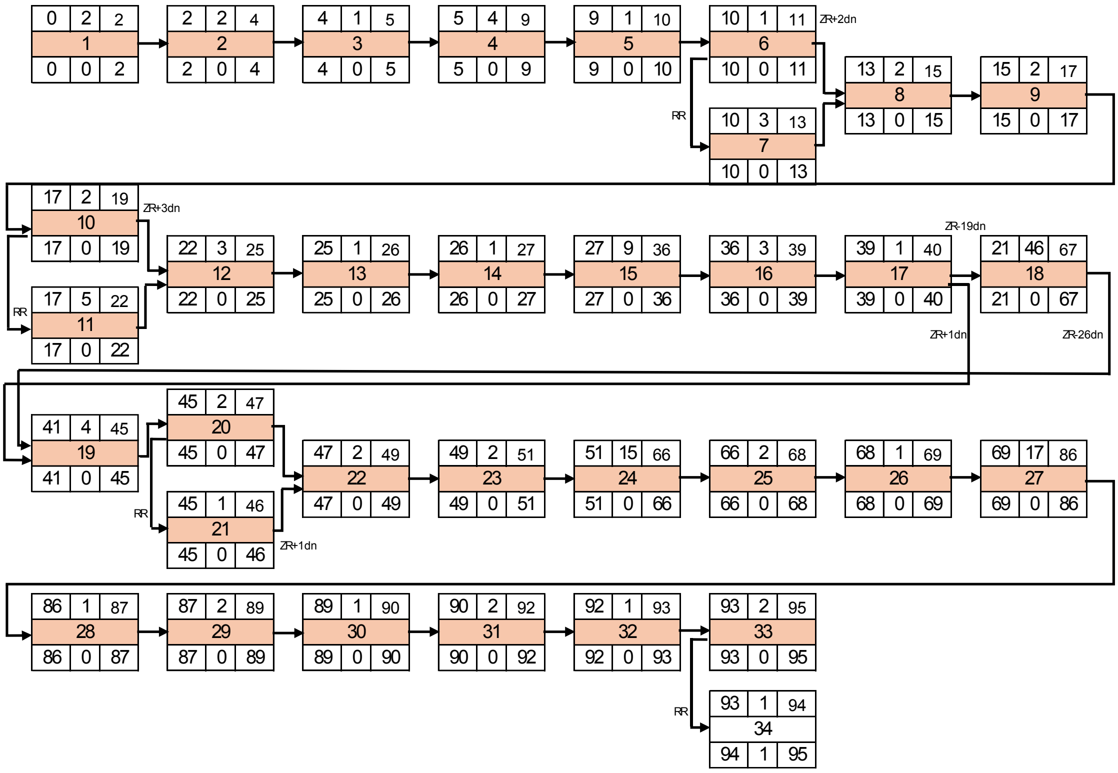


Figure4. Critical path for the project to eliminate time losses in the production process.

Source: Own work.

A list of tasks was meticulously prepared for the purpose of analysing the project using the critical path method (CPM) and creating a network diagram. It should be noted that this list does not include summary tasks or milestones; however, it does contain numbers, estimated duration and dependencies between individual activities. All these data are presented in Table 4.

Table 4.
Information needed to create a network diagram for the elimination project

Task number	Tasks	Duration (days)	Predecessors
1.	Defining the problem at a meeting with technologists and the production director	2	-
2.	Analysis of warehouse processes	2	1
3.	Development of transport operations in technology	1	2
4.	Determination of storage areas and assignment of responsible persons	4	3
5.	Creating a production layout	1	4
6.	Defining the tent hall as a warehouse	1	5
7.	Cleaning up the tent hall	3	6 RR
8.	Determining the layout of the shelves in the tent hall	2	6 ZR+2dn;7
9.	Determining the use of space on the racks	2	8
10.	Labelling shelves chronologically	2	9
11.	Implementation of Access Point in the tent	5	10 RR
12	Arranging pallets with parts on shelves	3	10 ZR+3dn;11
13.	Designation of a storage area for items awaiting entry into the WMS system	1	12

Cont. table 4.

14.	Changing the locations of storage areas to target locations in the IPO system	1	13
15.	Creation of an internal WMS system	9	14
16.	Synchronisation of WMS and IPO systems	3	15
17.	Test migration of data to WMS	1	16
18.	Generation of a new label formula for details by a partner	46	17 ZR-19dn
19.	Purchase of a warehouse code scanner	4	17 ZR+1 day; 18 ZR-26 days
20.	Updating the operating system supporting the scanner	2	19
21.	Preparation of training materials	1	20 RR
22.	Training employees on how to use the system	2	20; 21 ZR+1 day
23.	Implementation of the WMS system	2	22
24.	System performance testing	15	23
25.	Full data migration to WMS	2	24
26.	Full system launch	1	25
27.	Provision of technical support and monitoring after implementation	17	26
28.	Conducting a time study	1	27
29.	Feedback and corrections	2	28
30.	Automation of picking list generation by the foreman	1	29
31.	Testing the operation of the extended WMS system	2	30
32.	Checking the performance of the WMS system	1	31
33.	Data analysis and identification of areas for improvement	2	32
34.	Developing a plan for future updates and improvements	1	33 RR

Source: Own work.

The project team conducted a comprehensive risk analysis, employing a qualitative method to ascertain the potential effects and probabilities of these risks materialising. A comprehensive risk assessment card was created, supplemented with a plan to mitigate the identified risks. The documentation in question meticulously delineated the potential risks, their probability of occurrence, their potential impact on the project, and the specific countermeasures to be taken in the event of the risk materialising. The analysis indicated that the most significant risks to the implementation of the project were as follows:

- Employee resistance to change. The risk management plan included intensive communication activities and awareness building among staff.
- Inability to adapt labels defining details to the needs of the project. Mitigation measures involved developing a labelling system that allows for easy modification and adaptation.

Following a comprehensive review of all cost components, the total project budget was set at PLN 28,779.25 net. An analysis of the expenditure structure revealed that the largest cost item was investment in material resources. This predominance of material costs was a direct consequence of the necessity to thoroughly modernise the warehouse, which served as the primary location for the execution of project tasks.

All defined project objectives were successfully achieved, including in particular the implementation of a warehouse management system (WMS) and a comprehensive reorganisation of the warehouse space. The project was successful in achieving the expected results within the set budget and schedule. The project successfully implemented a new system, which resulted in a 55% reduction in order picking time and an enhancement in work organisation.

5. Conclusions

The study, which was conducted at SOR-DREW S.A. with a focus on enhancing material flow within the warehouse, yielded empirical evidence that demonstrated the efficacy of integrating the Lean Logistics concept with sophisticated IT systems, in the context of a perfect fit with the specifics of single-unit and small-batch production. On this basis, the following conclusions were arrived at:

1. It is imperative that companies adopt an individualised approach to production organisation, with the symbiosis of logistics and production being the pivotal factor in achieving success. It is imperative that there is close and properly structured cooperation between these two areas in order to ensure a smooth flow from raw material to finished product.
2. Inefficiency in the management of the flow of raw materials and semi-finished products is a direct cause of significant time losses, resulting in production delays.
3. The proprietary WMS system developed is an example of an innovative approach, fully adapted to the specific needs of a metal products manufacturing company.
4. The utilisation of chronometry as a research instrument facilitated the precise and comparative measurement of the time consumption of the picking process before and after the implementation of the system.
5. The research demonstrated a substantial decrease in the time required for the selection of components, with a reduction of 55%. This decline resulted in a significant decrease in the total operational duration from 20 minutes and 23 seconds (utilising the manual method) to 9 minutes and 5 seconds (employing the WMS system).
6. In view of the favourable outcomes of the analysis, a comprehensive improvement project was formulated, with a focus on the synergy of the physical reorganisation of the warehouse infrastructure (e.g. separation of a permanent zone, signage) and the full implementation of an integrated WMS system.
7. The success of the implementation project, based on a cascading approach and careful risk analysis, confirms that the strategic integration of IT systems with physical infrastructure is an effective way to introduce lasting changes in manufacturing processes.

The study demonstrates that strategic investment in innovative technological solutions (proprietary WMS) and workspace reorganisation is an effective method of eliminating time losses in the production process. The employment of a methodical approach to project management has facilitated a pivotal transformation within the domain of production logistics. This development substantiates the assertion that, in an era characterised by intensifying competition, the optimisation of time through the integration of technology, processes and work organisation is paramount.

References

1. Antczak, D., Puchała, M. (2014). Lean Management jako metoda optymalizacji procesów logistycznych w magazynie firmy X – cz. I. *Czasopismo Zarządzanie Innowacyjne w Gospodarce i Biznesie*, *no. 2(19).* Łódź: AHE, pp. 41-53.
2. Baudin, M. (2005). *Lean Logistics: The Nuts and Bolts of Delivering Materials and Goods*. New York: Productivity Press, p. 30.
3. Cybulska, D., Kij, A., Ligaj, M. (2014). *Organizowanie i monitorowanie przepływu zasobów i informacji w procesie produkcji*. Warszawa: WSiP, p. 33.
4. Dębski, S. (1993). *Ekonomika i organizacja przedsiębiorstw*. Warszawa: WSiP, p. 48.
5. Karbownik, A. (2017). System zarządzania projektami w przedsiębiorstwie produkcyjnym – przykład wdrożenia. *Zeszyty Naukowe Politechniki Śląskiej. Organizacja i Zarządzanie, no. 101.* Gliwice: Wydawnictwo Politechniki Śląskiej, pp. 223-229.
6. Karbownik, A. (2017). *Zarządzanie projektami w przedsiębiorstwie*. Gliwice: Wydawnictwo Politechniki Śląskiej, p. 224.
7. Karbownik, A. (2021). *Przedsiębiorstwo zorientowane projektowo.* Gliwice: Wydawnictwo Politechniki Śląskiej, pp. 58-66.
8. Krawczyk, S. (2000). *Logistyka w zarządzaniu przedsiębiorstwem*. Wrocław: AE, p.103.
9. Musioł-Urbańczyk, A., Podgórska, M., Sorychta-Wojsczyk, B., Wielicka Gańczarczyk, K. (2021). *Zarządzanie projektami: podręcznik do zajęć praktycznych.* Gliwice: Wydawnictwo Politechniki Śląskiej, pp. 89-96.
10. Ohno, T. (1988). *Toyota Production System. Beyong Large-Scale Production.* New York: Productivity Press, p. 18.
11. Serafin, E. (2014). Systemy informatyczne w logistyce. *Czasopismo Logistyka*, *no. 3,* pp. 5655-5660. Poznań: Sieć Badawcza Łukasiewicz - Poznański Instytut Technologiczny.
12. Szymonik, A. (2017). *Proces, rozmieszczenie urządzeń, sposoby przepływu produkcji, normy*. Retrieved from: http://gen-prof.pl/z_p_3.pdf, 15.10.2025.