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The impact of WMS implementation on work productivity. The case of three distribution warehouses

Wpływ wdrożenia systemu WMS na produktywność pracy. Przypadek trzech magazynów dystrybucyjnych

Abstract. Solutions of Industry 4.0 cover more and more areas of the economy. In logistics, digitization applies to each of the functional areas. Introducing IT solutions in logistics leads to an increase in the reliability of communication, faster stock rotation, and a higher level of service. It enables higher work efficiency and overall productivity. Changes in work productivity in three warehouses as a result of the implementation of a WMS class system and accompanying necessary changes in the equipment and organization of warehouse space was analysed in this work. The source of data for the analysis was the measurement of labour productivity for 12 months: three months before the implementation of the WMS and nine after its implementation. Work productivity after the implementation of the WMS increased by 40% compared to the level before it. The period of introducing WMS and obtaining an increase in personnel productivity was at least six months. Labour productivity in the analysed period increased in each month of the analysis. Only one of the three warehouses showed stabilization of workforce productivity at a level 50% higher than before the implementation. The research results confirm that the presence of WMS in the warehouse makes it possible to reach a significant increase in work productivity in warehouses.

Key words: WMS, warehouse, labour productivity

Synopsis. Cyfryzacja obejmuje coraz więcej obszarów gospodarki i życia społecznego. W logistyce obejmuje każdy z obszarów funkcjonalnych. Podstawowe cele, jakie są realizowane poprzez wdrożenia systemów informatycznych to wzrost szybkości i niezawodności obsługi, obniżenie strat, wzrost wydajności pracy, obniżka kosztów. W pracy analizowano zmiany produktywności pracy w trzech magazynach w wyniku wdrożenia systemu klasy WMS i koniecznych zmian w zakresie wyposażenia oraz organizacji przestrzeni magazynu. Podstawą analizy były wyniki pomiarów produktywności pracy w okresie 12 miesięcy: trzech przed wdrożeniem systemu i dziewięciu po wdrożeniu systemu. Stwierdzono, że produktywność pracy po pół roku od wdrożenia wzrosła o 40% w stosunku do poziomu przed wdrożeniem systemu WMS. Okres produkcyjnego uczenia się po zmianach wynosił co najmniej sześć miesięcy. Tylko w jednym z trzech magazynów zaobserwowano

stabilizację produktywności pracy na poziomie o 50% wyższym niż przed wdrożeniem. Wdrożenie systemu WMS w istotnym stopniu przyczynia się do wzrostu produktywności pracy.

Słowa kluczowe: WMS, magazyn, produktywność pracy

Introduction

The 20th century brought enormous progress in the field of Information Technology. Currently, one cannot efficiently manage an enterprise without vital IT systems, and the larger the company, the larger its needs within the scope of IT systems. The IT-supported processes in big companies are numerous and overly complex. The smaller the scale of operations, the easier it is to function without IT support. For the IT systems to correctly fulfill their purpose in the enterprise, they must reflect the company's operation, which is possible thanks to integrated IT systems (IITS). They are usually of modular structure, which allows their construction from previously designed "bricks" and inclusion in the IT support of various areas of the firm's operation, from single processes to comprehensive support.

The origins of IITS date back to the systems whose role was to manage the levels of stock, the Inventory Control (IC). The next stage of development is the emergence of MRP (Material Resources Planning), i.e. a system for planning the material needs, which answers the question of when and where the resources are needed. Further works over MRP resulted in the creation of MRP-II (Manufacturing Resources Planning) system for planning the production resources, which in turn was enriched concerning MRP with planning the auxiliary materials, fixed assets, human resources, funds, time, and others [Długosz 2009]. Usually, after the correct implementation of the IT system the increase in production efficiency and the sales results are achieved [Rut and Kulińska 2013].

The priority goals of implementing the IT systems are synchronizing the flow of products and services in the supply chain and the cooperation with the business partners. The choice of technology ought to be preceded by an in-depth analysis, as often many functionalities of the applied systems remain unused or are poorly suited for the company's specifics. Therefore, it is necessary to first define and optimize processes, and to them match the best solutions from the scope of IT, technology, and automation. Unfortunately, often the opposite happens, i.e. firstly, the companies put into operation expensive and complicated solutions and then consider how to use them effectively [Ozga 2011]. It is also observed that in the micro and small enterprises the IT implementations are rarer and include a smaller functional scope [Wicki and Franc-Dąbrowska 2013]. It results from the relationship of costs to the advantages resulting from their implementation. In small-scale operations, cost reduction and increase of productivity after implementation of IT do not always compensate for the costs of investment in IT, or the period of return on the investment is extensive [Wicki and Jałowiecki 2010]. The factor forcing the introduction of IT systems is, especially in logistics, efficient cooperation with other companies in the supply chain.

Goal and methodology

The aim of the paper is to assess the impact of WMS introduction and related to its organization of work in the distribution warehouse on work productivity.

As part of that goal, the following research tasks were carried out:

- characteristics of changes in the physical distribution of goods in warehouses,
- determination of changes in work efficiency in the researched warehouses.

The time of preparation of one order line (item) was adopted as an indicator of efficiency in the paper. This time is counted from the moment of receipt of the order to the moment of the shipment, i.e. issue to the carrier. This time consists of such elements as internal warehouse manipulation, picking, shipping, and administrative work. Thus, it is the sum of all warehouse workloads.

For the purposes of the study, data were collected on the following values every month:

- number of prepared (sent) lines of the order,
- total working time of all employees in the warehouse in minutes.

The data was obtained from the company's internal registry system for 12 months, including three months before the introduction of the new system and nine months after its introduction.

Based on monthly data, performance indicators were determined according to the following formula: number of items sent / staff working time. The indicator was calculated separately for the three examined warehouses and jointly for all warehouses. The dynamics indicator was used in the assessment of performance changes in time. As the comparative period, the results obtained for a given warehouse and in general for all warehouses within three months before the introduction of changes were adopted. The results were evaluated in two periods: the phase of changes introduction and the phase of full implementation.

The period of the first three months from the launch of the new system was classified as the phase of introducing changes. The period from the seventh to the ninth month after commencing the operation of the system was classified as the full implementation phase.

Warehouse Management System (WMS)

The Warehouse Management Systems are specialist software that improves all processes taking place inside the warehouses. They are of great significance in the enterprises that serve the daily large number of varied shipments, originating from many suppliers and directed at many recipients, where a high complexity of processes occur, as well as the necessity to monitor them. Concerning that, they are extraordinarily important to logistic operators, e.g. 3PL and collaborating enterprises.

The implementations of new tools are often perceived negatively by the employees, who are to use new solutions directly; hence, they display resistance to change [Selander and Henfridsson 2012]. The employees frequently identify new solutions

with an increase in their scope of work and its complications. Learning new solutions is also forced. Thus, it is extremely important to involve future users, e.g. warehouse workers, in the customization of software already at the stage of introduction. When the employees understand the assumptions and goals, they often get involved in the project, are positive towards it, thanks to which new work organization is quickly accepted [Majewski 2013].

Correctly designed and implemented WMS should take into consideration all processes and activities taking place inside the warehouse. The usefulness of warehouse management systems is very often brought down only to the role of recording inventories and flows of materials, and significant benefits result from optimization of all processes of storing and other warehousing activities [Dotoli et al. 2015]. Very often the employee decides where a given pallet should be allocated, which causes it to go to a random place. In such a case there is no question of optimizing storage. Moreover, lacking automatic system control, inactive positions often appear, which are not identified [Kunert 2020]. It is the system, in accordance with assumed algorithms (FIFO, FEFO, LIFO), that should decide about the distribution of materials and the order of their collection and release [Majewski 2006]. Therefore, the proper configuration of implemented system is particularly important, including the possibility of periodic optimization of product distribution or transport routes [Głodowska and Świderski 2019]. Introduction of the WMS usually minimizes the problems related to the unforeseen disturbances in the flow of information, the time of warehouse operations is shortened, and the efficiency of processes and effectiveness of the facility increase [Bartosiewicz 2017, Jankowska and Łukasiak 2017, Grzelak and Owczarek 2019].

The introduction of the WMS, but also other systems, allows to shorten the time of process implementation and reduce the risk [Ślaski 2018]. It contributes to the increase in the competitiveness of the supply chain in which the company participates, and indirectly to better results of entities participating in the chain. Usually, greater benefits are obtained in such chains, in which each of the partners has not only introduced solutions allowing the improvements of internal activities of the firm [Masłowski 2020], but also enhancements within the scope of information exchange and coordination between partners. Thus, one should agree with the statement that IT solutions are indicated among the most important areas for improving the functioning of supply chains [Rut and Wengel 2019]. Some researchers also imply that the increase in the efficiency of warehouse services in Poland was largely due to the application of modern IT systems [Sobczak 2020], although it is not always possible to determine the net impact of such implementation on the results [Jałowiecki 2018]. Nevertheless, both the use of emerging opportunities and meeting the challenges related to the digitization of the economy, including logistics, will be a key factor in the success of companies [Gajdzik 2019]. It should be emphasized that IT implementation is not a one-off activity. The systems are constantly enriched with new functions; hence the introduction of a given system, e.g. WMS, is the beginning of a continuous cycle of advancements and introductions [Jurczak 2019]. Additionally, in many small and medium-sized enterprises, the application and development of IT solutions may not be profitable due to the small scale of operations [Klepacki and Wicki 2014, Banaszyk 2020].

Process of WMS implementation

The general principles and methods of designing and implementing a WMS class warehouse management system provide for several basic steps that should be taken in order to avoid post-introductory problems [Bobiński 2009, Wiązowski 2018]. These are presented below.

1. Assessment of external conditions, i.e. the impact of the environment of the warehouse. During this process, many substantial questions about the predominant goals of logistics need to be answered:
   - Analysis of the structure and flow of goods in the supply chain,
   - Development of synthetic indicators and norms for those indicators, which aims to assess the warehouse operation.
2. Review and analysis of the warehousing processes. Thanks to that we can determine what functionalities of the necessary system are required. All logistics processes are analysed: from the receipt to the warehouse, through storage and completion of stock, co-packing, to shipment. What is important, they are examined both in terms of the flow of materials and accompanying them flows of information.
3. Design and commissioning of the system. This is the last stage of implementation which, like the concept phase, requires the creation of a detailed system specification. The very launch of the system in a given location should be carried out in the next steps:
   - system project,
   - parametrization of standards and programming of specific extensions,
   - configuration of IT system, i.e. mapping the physical structure of the warehouse, storage zones, definition of the logical warehouses, input of data relating to articles, contractors, etc.,
   - testing and training of personnel,
   - starting the system.

The enterprise must be prepared for the period of organizational learning of the new system causing a temporary decrease in productivity, which in this time can only be counteracted with extra employment or overtime, which is usually not calculated as a cost before implementation. Therefore, a plan is needed for gradual, as quick as possible, and at the same time efficient transition to the new management system.

The scope of activities that should be performed before the decision on purchasing and implementing an appropriate IT system is equally important as the choice of system and its price. It is also important to be aware that it is necessary to wait for obtaining the assumed implementation results for up to several months in the case of correct diagnosis of needs. Only after such time, the assumed performance is achieved, the presumed benefits can be accomplished, and the users of the system become independent.

Characteristics of logistics and warehouse processes in the enterprise

The surveyed company is a 3PL logistics operator and provides a number of standard services offered by this type of operators, such as:

- storage: in own warehouses or service in customer's warehouses,

- in-warehouse services:
  - unloading and receipt; many levels of control from visual to detailed,
  - storage; many types of storage places from small shelving of 0,072 m^3 to large pallet positions of 8,64 m^3,
  - picking; preparation and shipment in 24 hours from the date of placing an order, in special cases in four hours from the moment of order placement,
  - co-packing; additional services of creating sets, disassembling, assembling complex elements, e.g. stands, foiling,
  - labelling, attaching additional markings, labels to products,
  - loading;
- transport: organization and selecting appropriate transport taking into account the optimization of costs and maximum use of available cargo space;
- inventory management: inventory analysis, inventory management, triggering deliveries;
- administrative services: invoicing on behalf of the client, monitoring of client's receivables.

The possibility of improving the efficiency of processes and reducing both operational costs and costs connected to the low quality of processes resulted from the implementation of the WMS, the task of which is to better supervise the flow of goods and provide information that allows shortening the time of completion and control.

Characteristics of the analysed warehouses

The analysis covered three warehouses with an area of approximately 3,000 m^2 each, dedicated to the handling of fast-moving products. The Comarch ERP XL system was introduced in the warehouses. A WMS class module called High Storage Module (HSM) was put in operation.

The implementation of a WMS class warehouse system required changes both in the warehouse equipment and in the organization of warehouse processes. The most important changes concerned the method of handling warehouse processes (implementation using WMS), defining the picking path, and optimizing the address of goods in the warehouse depending on the number of pickings and frequency of occurrence of goods in orders. The changes also concerned the method of notification and procedure of goods acceptance, description, and location of warehousing units, as well as generating and circulation of documents. These areas were not subject to detailed analysis within the framework of this study; only the total workload was determined. It should be emphasized here that the change in labour productivity presented in this paper results from many changes introduced together with the implementation of the WMS. There is a lot of evidence that the increase in labour productivity in warehouses resulted from the reorganization of space and changes in storage equipment [Park et al. 2018, Pereira et al. 2020], may be related to the introduction of new reading devices [Nair et al. 2018] and a new picking method [Valchkov and Valchkova 2018], route planning [Mahalakshmi 2019] or even with the appropriate data architecture [van Geest et al. 2020].

After the implementation of the system, in the description of each unit, in addition to the standard information with the reference number and word description, also the following information is recorded: series and best before date (suggested consumption date), average number of items in a single order, and frequency of goods appearing in the orders. This allows automation of data analysis using the software's algorithms.

The implementation of the WMS was related to the changes in the warehouse space organization. One of the more important changes was the division of the warehouse into two zones: storage and completion, instead of dividing it into areas in accordance with the group of goods (Figure 1). Within the storage zone, the areas were distinguished for storing goods from various groups that must be separated. The goods in the storing area are placed on the homogenous pallets, on the racks, instead of positioning them on the floor level in the joint storage and picking area.

Based on the current inspection of inventory levels, the movement of goods is forced from the storage area to the completion zone. The units of the same goods with varied best before date are divided in terms of their location. The FEFO queue is in effect.

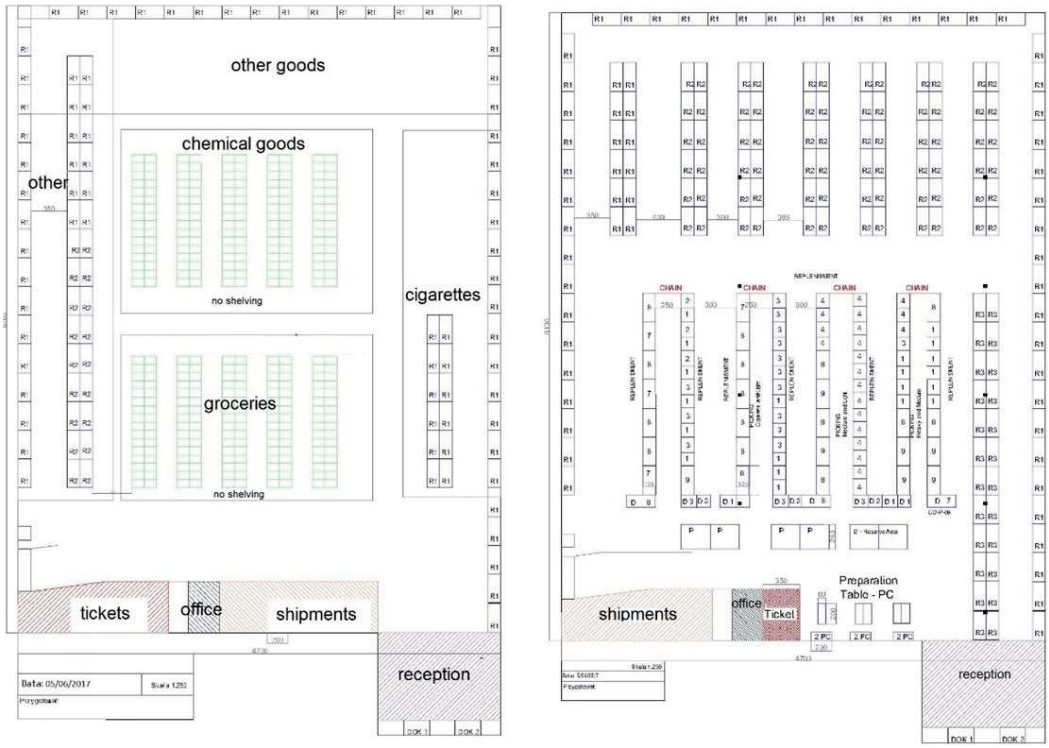

Figure 1. Warehouse scheme and goods location before (left diagram) and after implementation of the WMS (right diagram)

Rysunek 1. Schemat magazynu i lokalizacja towarów przed (lewy diagram) i po wdrożeniu WMS (prawy diagram)

Source: own research.

The WMS has a module for analysis of goods rotation. This module is based on the ABC method. Using the ABC analysis, twice a month the changes are made to the order in the completion zone to achieve the optimal, due to the length of the complete path, the arrangement of products in the warehouse, within the zones for individual products.

After the implementation of the WMS, the processes of completion of order and release of goods were amended. The orders are generated in an electronic form in the WMS. Based on the analysis of availability and location, the goods system generates transfer orders and a complete list taking into account the shelf life of goods for sale and location of goods' units. The order of products on the completion list results from the optimization of the path to be followed by a picker. Before the implementation of the WMS, the picker had to locate products independently, which required a perfect knowledge of their distribution within the warehouse. It was thus not possible to optimize the distribution without disrupting work. As a result of implementing the WMS solutions, the completion path was significantly shortened. Before the implementation, the distance covered by the employee during the completion of a single order was about 410 m. After the changes, the length of the picking path was shortened by an average of 59%, to 170 m per order (see Figure 2). In order to fulfill 100 orders, the employees had to travel 41 km before the reorganization of the warehouse and 17 km after the changes. The time needed for picking was shortened and productivity increased.

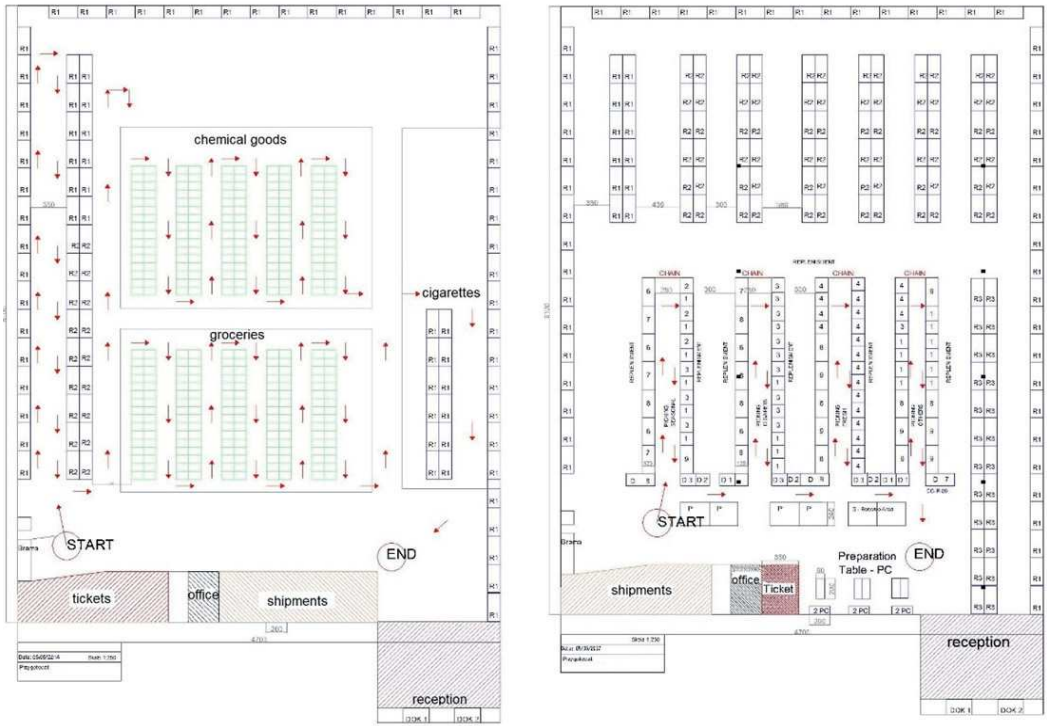

Figure 2. The picking path in the warehouse before (left diagram) and after the implementation of WMS (right diagram)

Rysunek 2. Ścieżka kompletacji w magazynie przed (lewy diagram) i po wdrożeniu WMS (prawy diagram)

Source: own research.

To optimize the quantity and availability of goods, an ABC cross-analysis was used according to the criterion of the number of pieces of goods issued daily and the frequency of appearing of a given item in orders. Data from three months before the implementation of the WMS system was used as the input information – 1950 products were examined. The ABC analysis (1) was performed, considering the criterion of the number of items issued daily, followed by the ABC analysis (2), taking into account the percentage of orders in which a given product appeared as the criterion. The results are summarized in Tables 1 and 2 About 14% of products accounted for as much as 86% of issued units.

Table 1. The results of the ABC (1) analysis
Tabela 1. Wyniki analizy ABC (1)

Groups of goods	The number of items in the assortment	Percentage share of goods		Total of shipped items	Percentage share of items	
A+	104	5.33	14.21	4 416 752	65.19	85.77
A	173	8.87		1 394 593	20.58	
B	692	35.49		854 500	12.61	
C	981	50.31		109 651	1.62	
Total	1950	100.00		6 775 496	100.00	

Source: own research.

Similar results were obtained in the ABC (2) analysis in accordance with the frequency of appearance of articles in the orders (see Table 2). (A+ – 10% orders, A – 4% orders, B – minimum 0.5% orders). Approximately 17% of goods appeared not less frequently than in every 25th order.

Table 2. The results of the ABC(2) analysis
Tabela 2. Wyniki analizy ABC(2)

Commodity group	Number of item's position	Percentage share of goods		Total of shipped lines	Percentage share of items	
A+	161	8.25	16.66	189 383	60.53	79.28
A	164	8.41		58 647	18.75	
B	578	29.64		59 849	19.13	
C	1047	53.70		4 983	1.59	
Total	1950	100.00		312 862	100.00	

Source: own research.

These analyses were combined, and the product categories were created, which were used to plan their distribution in the preparation zone. Most frequently outgoing goods, i.e. present in the highest number of orders, were located closest to the completion and shipment zones, whilst goods rarely present in orders were put at the end of the racks, furthest from the preparation and shipment zone.

Change in employee performance after the implementation of WMS

The introduction of WMS, the change of warehouse layout, and the new distribution of goods led to the alteration in work performance.

Table 3. Productivity changes in the examined warehouses
Tabela 3. Zmiany produktywności w badanych magazynach

Month	Number of product lines, working time and labour productivity											
	warehouse 1 (W1)			warehouse 2 (W2)			warehouse 3 (W3)			total		
	lines	working time [min]	productivity	lines	working time [min]	productivity	lines	working time [min]	productivity	lines	working time [min]	productivity
03b	152 796	235 026	0.65	183 132	282 650	0.65	41 531	64 320	0.65	377 459	581 996	0.65
02b	129 876	201 019	0.65	186 795	277 874	0.67	200 772	322 900	0.62	517 443	801 793	0.65
01b	150 734	218 970	0.69	156 908	237 675	0.66	204 845	320 095	0.64	512 487	776 740	0.66
01a	151 313	206 760	0.73	169 489	230 284	0.74	208 195	278 980	0.75	528 997	716 024	0.74
02a	175 369	229 177	0.77	182 917	231 450	0.79	194 553	268 920	0.72	552 839	729 547	0.76
03a	166 656	197 280	0.85	210 199	242 220	0.87	226 396	297 315	0.76	603 251	736 815	0.82
04a	145 996	174 660	0.84	193 205	227 190	0.85	221 446	292 701	0.76	560 647	694 551	0.81
05a	180 198	219 697	0.82	166 766	174 350	0.96	207 486	260 350	0.80	554 450	654 397	0.85
06a	171 165	213 320	0.80	201 023	189 300	1.06	212 251	270 540	0.79	584 439	673 160	0.87
07a	157 061	168 870	0.93	202 567	201 720	1.00	231 039	296 670	0.78	590 667	667 260	0.89
08a	154 339	174 570	0.88	188 277	187 500	1.00	166 763	197 220	0.85	509 379	559 290	0.91
09a	173 304	193 020	0.90	188 796	190 680	0.99	161 955	171 820	0.94	524 055	555 520	0.94
Before 03b–01b (3-month avg)			0.66			0.66			0.63			0.65
After, 07a–09a (3-month avg)			0.90			1.00			0.84			0.91
Change (before = 100)			137			151			133			140
Average percent change per month			2.34			4.03			2.49			2.92

Source: own research.

In Table 3 the results were presented of productivity achieved in individual warehouses in 12 months of measurements for each warehouse. The analysis period included in the table related to each of the analysed warehouses three months before (lines 01b–03b) and nine months after implementing the WMS (lines 01a–09a).

The changes made in the process allowed for the shortening of the complete path, and also the acceleration of the possibility to find the sought goods. Work efficiency in the studied facilities increased. On average, before the implementation 0.65 positions per working minute were completed. Directly after introducing the system and changes in the spatial organization in warehouses, as well as the alteration of processes, the slight increase in productivity to approx. 0.75 positions per minute took place. After half a year post-implementation, the productivity equaled on average 0.91 positions per working minute. Only in one warehouse (M2) the productivity stabilized on the level of 1 position per minute.

In each of the studied warehouses, the increase in work performance was noted as a result of implementing the WMS, as well as changes in the spatial organization of a warehouse and completion techniques. In nine months after applying modifications, the increase in work performance in warehouses took place, measured by the time of completion per line, on average by 40% compared to the period before the alterations. In individual warehouses, it was from 37 to 51%. In monthly terms, it was on average up to 44% in month nine (see Figure 3). Also, the differences were noted in the post-implementation time, after which the performance improvements were achieved. In warehouses W1 and W2 it took place after two months from the implementation of the system, and in W3 only after four months. The factors that led to these differences were not researched in detail, but they could result from the involvement and experience of working teams in individual

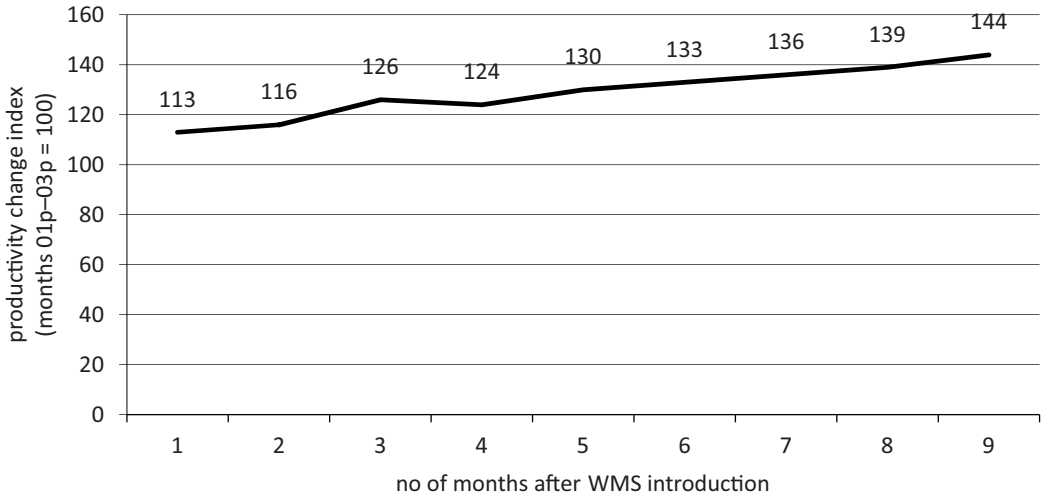

Figure 3. Average change in labour productivity in warehouses in the nine-month period after the implementation of the WMS

Rysunek 3. Średnia zmiana wydajności pracy w magazynach w okresie dziewięciu miesięcy po wdrożeniu WMS

Source: own research.

warehouses. On average, in the post-implementation period analysed in the study, there was an increase in labour productivity at a rate of about 3% per month, and in the last three months covered by the study (07w–09w), there was a stabilization of productivity, although it cannot be stated that no further increase will occur. Considering the stabilization of the productivity level in the W2 warehouse, it can be concluded that the further increase in labour productivity will be limited, and the implementation effects are fully achieved not earlier than after six months, with the commitment and high experience of the staff. Further growth may occur with additional improvements or gaining experience by employees, but this cannot be observed based on this study.

Costs after the implementation of WMS

The implementation of the WMS brought with it new costs. In addition to IT expenditure, such as software, network access, and hardware, expenses were incurred related to equipping the warehouse. The introduction of high storage racks created the need to purchase forklifts. The increase in fixed costs was estimated at 9%. Implementation costs were not, however, the subject of the study, but must be taken into account in the decision-making process. The increase in labour productivity and associated savings may be correlated with higher costs of technical equipment, as well as the consumption of materials and energy.

Summary

The introduction of IT solutions supporting the implementation of logistics processes is now a necessity. The progressive digitization of the economy enables the effective use of computer-controlled systems in almost every area of logistics. IT solutions currently concern not only the improvement of information processing and exchange but more and more often supporting the processes of physical movement of units. Often, as in the surveyed warehouses, the implementation of, for example, a WMS required not only the purchase of an IT solution but also warehouse technical equipment. Additionally, it is usually necessary to reorganize processes, including such aspects as the form of communication with the client, generating orders, reporting, and settlements. In the warehouses surveyed, the implementation of the WMS system was associated with a partial change in the organization of the warehouse space, the introduction of a new type of racks, but above all with a change in the technique for classifying goods and the rules for locating goods in space. A storage zone and a picking zone were separated. Goods were divided and arranged according to their rotation and share in turnover.

As a result of the implementation, an increase in labour productivity was achieved. After the first implementation period (six months), the productivity increased by 40%, and the number of completed items increased from 0.65 to 0.9 per minute. The study showed that the period of productive learning of employees after the implementation of the IT system in the warehouse is at least six months. After this period, the level of labour productivity was stabilized. It should be emphasized that the observed increase in labour productivity did not only result from the implementation of the WMS system, but also

from the accompanying changes in equipment, space layout, and work organization in warehouses.

The implementation of a WMS requires investments that lead to an increase in fixed costs. With rising labour costs, labour-saving investments seem to be a necessity. Cost reduction related to the increase in labour productivity, improvement of communication with internal and external partners, and avoidance of warehouse losses should compensate for the increase in infrastructure costs. Besides, there are benefits for partners in the supply chain, which increases its competitiveness. However, the issue of benefits obtained by partners in the supply chain resulting from the implementation of the WMS system for one or several partners was not the subject of this study. This should be the subject of further research.

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