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XIV INTERNATIONAL SYMPOSIUM OF YOUNG RESEARCHERS

Dedicated to the 80th anniversary of the Silesian University of Technology

Silesian University of Technology
Faculty of Transport and Aviation Engineering

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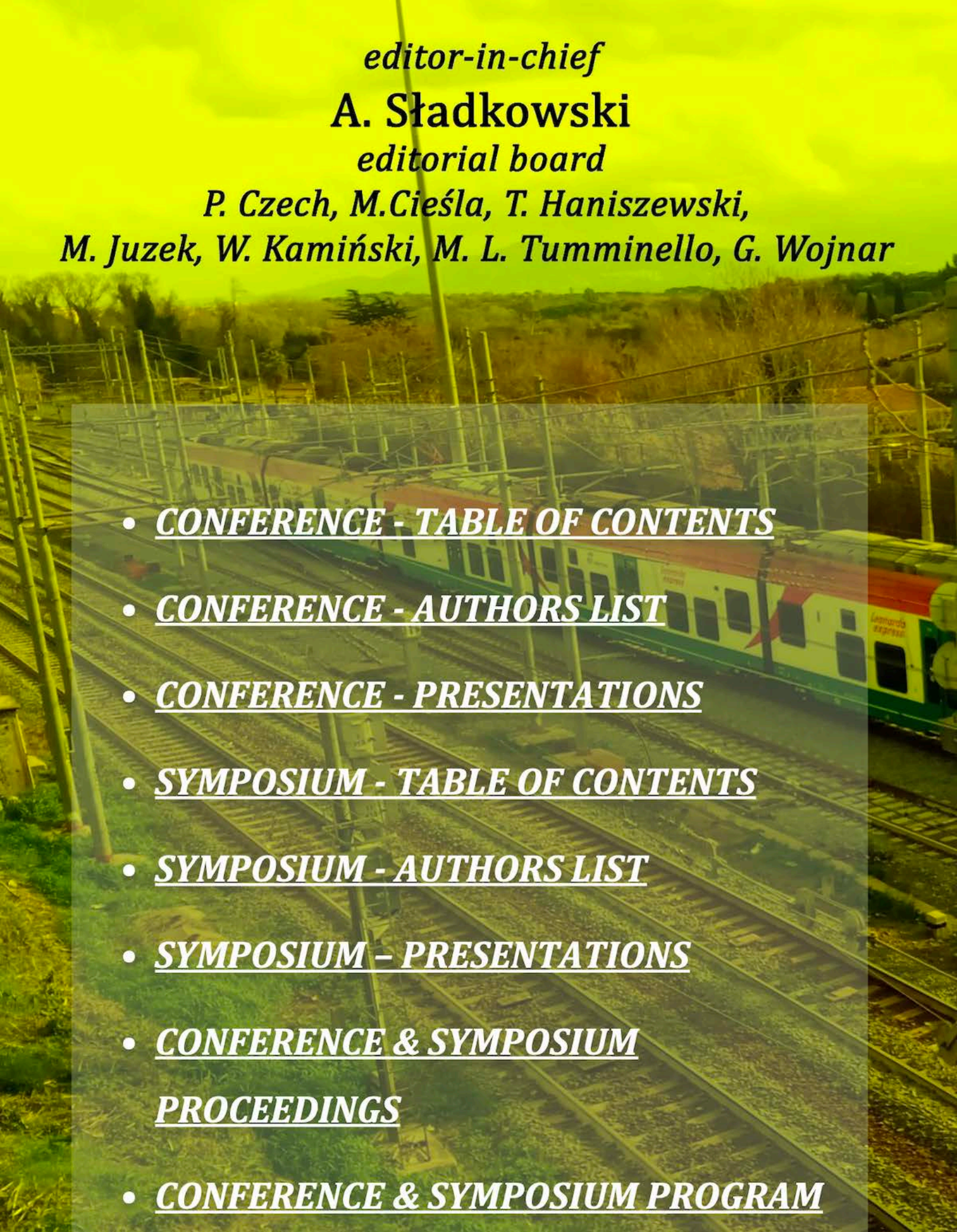

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Keywords: WMS, ROI analysis, logistics automation, WMS implementation

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ADVANTAGES AND DISADVANTAGES OF WMS SYSTEMS

Summary. This thesis explores the implementation of Warehouse Management Systems (WMS) and their impact on warehouse operations, inventory control, and business performance. It analyzes the advantages and limitations of WMS solutions, compares leading platforms, and presents real-world case studies, including both successful and failed implementations. Special attention is given to Polish businesses and the development of a custom ROI-based methodology to assess the economic feasibility of WMS adoption. The work concludes with practical recommendations and a dynamic ROI model designed to support decision-making in logistics and supply chain management.

1. INTRODUCTION

In today's increasingly digital and competitive environment, the efficiency of warehouse operations plays a crucial role in the success of supply chains. Warehouse Management Systems (WMS) are specialized software solutions designed to optimize and automate key warehouse functions such as inventory control, goods receipt, order picking, and shipping. By integrating WMS into logistics and production workflows, companies can significantly reduce operational costs, minimize human error, and enhance service levels.

The global demand for WMS solutions has grown rapidly, with various industries—retail, e-commerce, manufacturing, and pharmaceuticals—seeking scalable, flexible, and cost-effective systems. In particular, cloud-based and hybrid WMS models are gaining traction due to their adaptability and lower upfront costs compared to traditional on-premise systems.

This thesis aims to explore the core functionalities, advantages, and limitations of WMS platforms, assess their impact on warehouse performance, and examine real-world implementation cases, including the Polish market. A unique contribution of this work is the development of a dynamic ROI (Return on Investment) model, which provides a more realistic and time-sensitive approach to evaluating the financial viability of WMS deployment.

Moreover, as businesses face increasing pressure to digitize operations and respond rapidly to market demands, the strategic role of WMS becomes even more critical. However, the implementation of such systems is not without challenges—ranging from high initial investment costs and complex system integration to resistance from staff and risks of operational disruption. Therefore, this research also addresses the risks and barriers associated with WMS adoption, aiming to provide companies with a balanced and evidence-based view before undertaking such digital transformation initiatives.

Purpose of research. Conduct a comprehensive assessment of the effectiveness of implementing WMS systems in companies of various sizes, with the development of our own methodology for calculating dynamic ROI, adapted to Polish business.

Research objectives:

-Study the functions, types and evolution of WMS systems.

-Consider the advantages and disadvantages of implementation in practice.
-Analyze real cases in logistics, retail and production.
-Develop a dynamic ROI formula that takes into account time, cost and efficiency factors.
-Formulate criteria for choosing WMS for Polish enterprises.
-Provide practical recommendations to companies on WMS implementation.

2. THEORETICAL FOUNDATIONS OF WMS SYSTEMS

2.1. Definition and Functions of WMS (Warehouse Management System)

A Warehouse Management System (WMS) is specialized software designed to automate and optimize warehouse operations. The main goal of WMS is to increase warehouse efficiency through automated inventory tracking, control of goods movement, and integration with other business processes.The key functions of WMS include:

- **Receiving and storage of goods** – automated allocation of goods within the warehouse based on their characteristics, weight, dimensions, and expiration dates.
- **Inventory control** – accurate tracking of goods movement and stock levels, reducing the risk of stockouts or overstocking.
- **Optimization of picking and order assembly routes** – WMS enables selection of the most efficient paths for product movement, reducing the cost and time of order fulfillment.
- **Inventory audits** – automated stock checks that eliminate the need for warehouse downtime.
- **Integration with ERP and other systems** – seamless connectivity with accounting and logistics software, enabling end-to-end supply chain management.

Thus, WMS systems are a critical tool for warehouse organization, helping to minimize errors, increase accuracy, and accelerate warehouse operations.

2.2. Types of WMS

Modern WMS systems are classified according to their deployment method and interaction with a company's IT infrastructure. The main types are:

Cloud-based WMS

- Hosted on the vendor's remote servers and offered as Software as a Service (SaaS).
- *Advantages:* low initial implementation cost, scalable, accessible from anywhere.
- *Disadvantages:* dependency on internet connectivity, potential security risks.

In Fig. 1 we can see an example of cloud-based WMS system called Infor WMS.

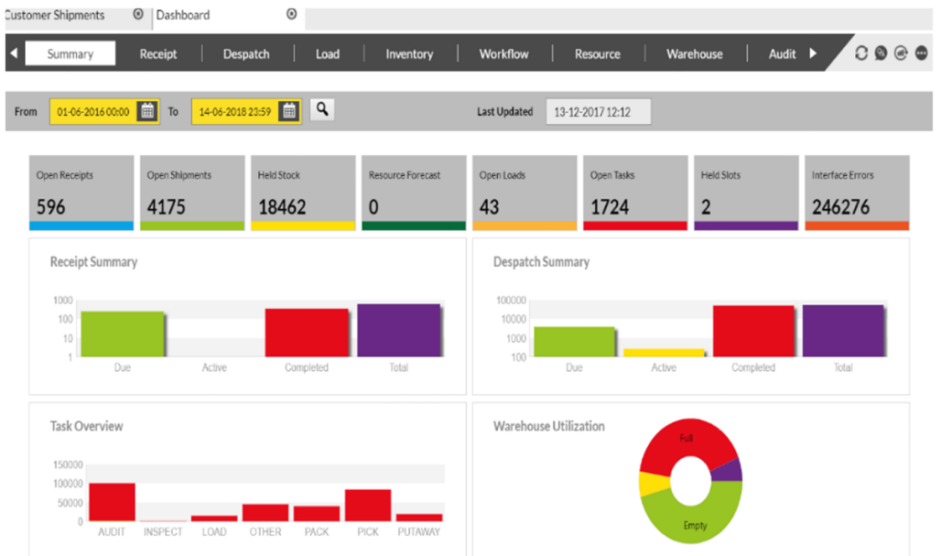

Fig. 1. Infor WMS

Local WMS

- Installed on the company's internal servers and managed by its own IT department.
- *Advantages:* full control over data, high customization potential.
- *Disadvantages:* high upfront investment, ongoing infrastructure maintenance required.

In Fig. 1 we can see an example of local WMS called Manhattan WMS.

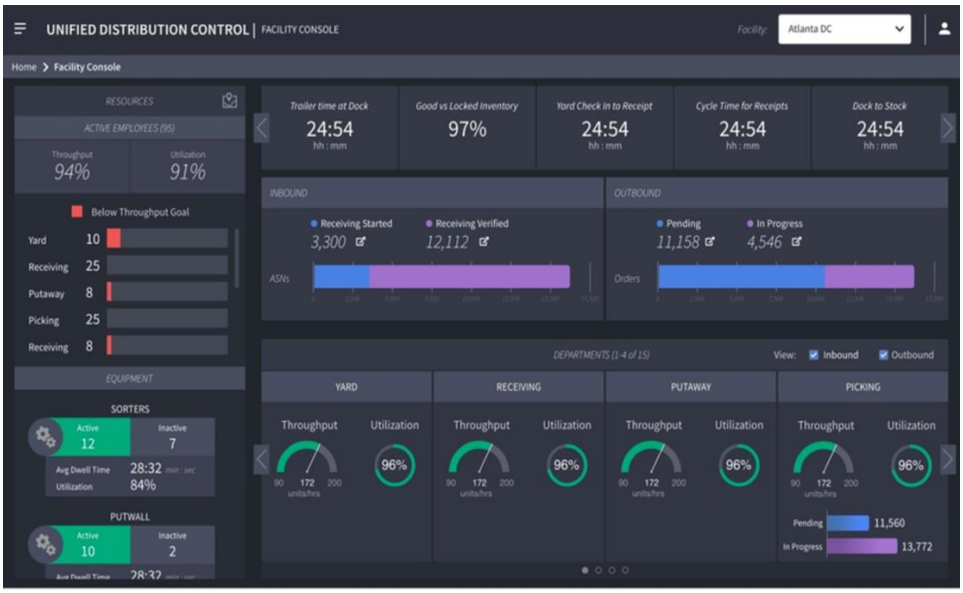

Fig. 2. Manhattan WMS

Hybrid WMS

- Combine elements of both cloud and on-premise solutions.
- *Advantages:* balanced approach to security, accessibility, and integration capabilities.
- *Disadvantages:* more complex setup and support.

In Fig. 3 we can see an example of Hybrid WMS called oracle WMS.

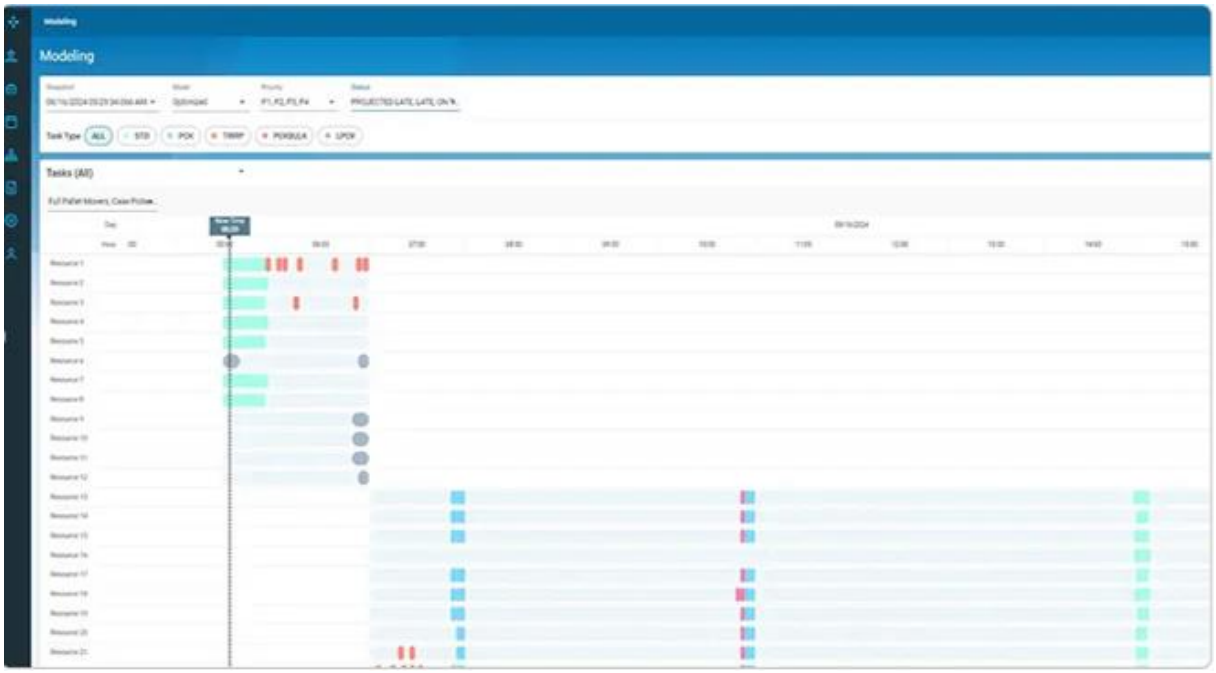

Fig. 3. Oracle WMS

The choice of WMS type depends on the company's needs, size, level of IT infrastructure, and budget.

3. ADVANTAGES OF WMS SYSTEMS

3.1 Key Performance Metrics of WMS

Key performance metrics of a Warehouse Management System (WMS) help evaluate how effectively the system manages warehouse operations and what benefits it brings to the business. One of the most important indicators is **inventory accuracy**, which reflects the level of alignment between actual stock and system data. Without automation, this accuracy typically ranges between 85–90%, but after implementing a WMS, it can reach 99% or higher. This improvement is due to real-time tracking of all product movements, automatic data updates, and the ability to conduct cycle counts without halting operations—ultimately reducing shortages and overstock.

Another critical metric is **order processing speed**, which measures the time from when an order is received to when it is shipped. A WMS optimizes picking routes, automates item selection and packing, and streamlines overall workflows. For example, if processing a single order previously took 2–3 hours, after WMS implementation it may be reduced to 30–40 minutes.

Warehouse space utilization is also a key performance indicator. It shows what percentage of available storage area is effectively used. WMS optimizes product placement by allocating goods to the most accessible and space-efficient locations, reducing "dead zones" and increasing usage from 60% to 85% or more.

Another important metric is the **out-of-stock rate**, which measures the percentage of orders that cannot be fulfilled due to insufficient inventory. A WMS helps prevent stockouts by monitoring inventory levels and automatically triggering replenishment orders when stock falls below predefined thresholds. As a result, the out-of-stock rate may drop from 10% to as low as 2% or less.

Labor productivity also improves significantly with WMS implementation. The system minimizes manual data entry, automates tasks, and optimizes worker movement throughout the warehouse. Productivity can be measured by the number of orders processed per employee per shift. For instance, a worker might handle 50 orders daily before WMS, and 80 after implementation, reflecting a notable efficiency gain.

Another key metric is the **return rate**, which reflects the percentage of orders returned due to picking errors, damages, or product mismatches. WMS minimizes such errors by tracking batches, serial numbers, and enforcing automated quality control. The return rate can drop from 5% to around 1% after WMS implementation.

Finally, WMS positively impacts **customer satisfaction (Customer Satisfaction Score, CSAT)** by ensuring faster order fulfillment, fewer errors, and improved communication through automated order status notifications. If CSAT was around 75% before WMS, it often increases to 90% or higher after, leading to greater customer loyalty and more repeat purchases.

3.2 Examples of WMS Implementation Across Different Industries

Implementing warehouse management systems (WMS) offers significant advantages for businesses, but the effectiveness largely depends on the specifics of each industry. Let's look at successful examples of WMS usage in logistics, retail, manufacturing, pharmaceuticals, and e-commerce.

Logistics

Companies involved in warehousing and transportation logistics benefit from WMS through the optimization of warehouse operations and faster cargo handling. For example, the international logistics operator DHL implemented WMS to manage large distribution centers. As a result, the system helped

reduce product search time in warehouses by 30%, cut order picking errors by 50%, and lower labor costs through process automation.

Retail

In retail, WMS is especially important for inventory management and preventing stockouts. The hypermarket chain Walmart uses WMS to monitor product availability in real time, which helps minimize losses due to shortages or excess inventory. After implementing the system, inventory accuracy in Walmart stores increased to 99.5%, and shelf restocking logistics became more predictable and automated.

Manufacturing

In manufacturing, WMS helps manage raw materials, track the movement of components, and coordinate shop floor operations with logistics departments. Toyota factories use WMS as part of their Lean Manufacturing approach. This has enabled optimized storage of components, reduced search time, and minimized waste. As a result, Toyota reduced raw material inventory by 20%, lowering warehousing costs and improving financial performance.

Pharmaceuticals

In the pharmaceutical industry, inventory accuracy and controlled storage conditions are critical. Pfizer implemented a WMS with automatic expiration date tracking and strict temperature control for storage. As a result, the percentage of expired medications in the supply chain decreased by 40%, and regulatory compliance became more transparent.

E-commerce

For online retail, WMS is a key tool for fast order processing and minimizing errors. The major online retailer Amazon uses advanced WMS systems in combination with robotic warehouses. This allows products to be located and shipped within minutes, ensuring high delivery speed. For example, it can take as little as 30 minutes from order placement to handoff to a courier.

4. DISADVANTAGES OF WMS SYSTEMS

Despite numerous advantages, WMS systems have a number of limitations and challenges that can act as barriers to their implementation. This chapter examines the main difficulties companies face when adopting such solutions.

4.1. High Cost of Implementation and Maintenance

One of the main obstacles to WMS adoption is its high cost. This includes several components:

- License or subscription fees – for cloud-based solutions, this means ongoing monthly payments; for on-premise systems, a one-time license purchase is required.
- Hardware expenses – barcode scanners, RFID tags, servers, and mobile terminals must be purchased.
- Customization and development – if standard system functions do not meet business needs, costly modifications may be necessary.
- Support and updates – technical support, software upgrades, and additional configurations can lead to extra expenses.

For large enterprises with extensive warehouse operations, such investments are often justified. However, for small and medium-sized businesses, WMS costs may be prohibitively high.

Fig. 4 shows the average price for buying local WMS systems. There is 4 types of WMS systems like SAP WEM, Manhattan WMS, Infor WMS and Blue yonder WMS. These prices were calculated for the 20000 m^2 warehouse and it can change with the number of users and area of warehouse.

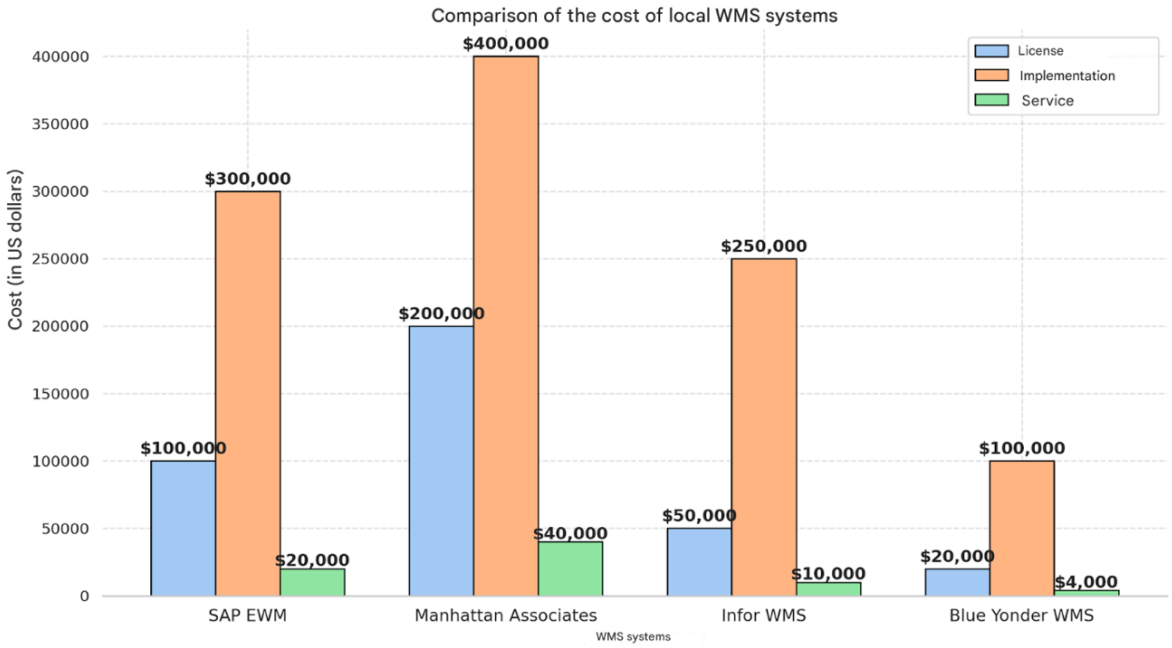

Fig. 4. Comparison of the cost for local WMS system for100 users

4.2. Complexity of Integration with Existing Systems

WMS solutions rarely operate in isolation—they need to be integrated with other IT systems (such as ERP, TMS, CRM, or accounting software). This process can be technically complex and expensive due to several factors:

- Inconsistent data standards – if the company's ERP or CRM system uses non-standard formats, extra development is required.
- Limited API capabilities – some WMS platforms have closed or restricted APIs, requiring middleware for integration.
- Legacy system conflicts – outdated IT infrastructure can prevent effective integration unless significant upgrades are made.

These challenges increase the time and cost of implementation, which can be particularly problematic for companies with complex or legacy systems in place.

4.3. Training Requirements for Personnel

Even the most advanced WMS is ineffective if employees are not trained to use it properly. Implementation typically involves:

- Training warehouse staff – employees must learn to use terminals, scanners, and system interfaces.
- Preparing IT specialists – WMS administration requires specific technical knowledge, which may require hiring or outsourcing.
- Changing warehouse processes – traditional workflows may become obsolete, requiring employees to adapt to new procedures.

Mistakes during the training phase can reduce operational efficiency and even increase error rates in the early stages of WMS use.

4.4. Limitations in Flexibility and Customization

Not all WMS platforms are equally suitable for different types of businesses. Common issues include:

- Limited out-of-the-box functionality – basic versions may not support specific needs, such as fragile item handling or multi-stage logistics.
- High cost of customization – adapting the system to unique processes can be expensive and require specialized developers.
- Vendor lock-in – some WMS providers offer closed architectures, making customization impossible without their direct (and costly) involvement.

Businesses with non-standard operations may find that selected WMS platforms do not meet their requirements, and adapting them becomes overly complicated.

4.5. Cybersecurity Risks

As warehouse operations become increasingly digital, the risk of cyberattacks and data breaches grows. Key threats include:

- Cloud-based WMS hacking – cloud systems are potential targets for cybercriminals.
- Internal data leaks – multiple employees may have access to WMS, increasing the risk of internal misuse.
- Data manipulation – incorrect or malicious data entry can disrupt inventory accuracy.
- IoT-related threats – if the WMS is integrated with smart devices and robots, attackers could potentially gain access to these systems.

Protecting against such threats requires encryption, multi-factor authentication, and regular security audits—all of which increase operational costs and system complexity.

An Example of Unsuccessful WMS Implementation: The Case of Finish Line Inc.

One of the most well-known examples of a failed warehouse management system (WMS) implementation is the case of the American company Finish Line Inc., specializing in retailing sports shoes and apparel. At the time of the incident, the company operated more than 900 stores across the United States and was actively developing its e-commerce business.

In 2013, the company’s management decided to undertake a large-scale digital transformation, which included implementing a new WMS system and an e-commerce platform. The implementation was carried out using a "Big Bang" approach — launching all system components simultaneously just before the peak sales season (the fourth quarter of the year, including Black Friday and Christmas sales). This approach later became the main cause of the project's failure.

Key mistakes made by the company:

- Lack of comprehensive testing and pilot implementation. The new WMS system was launched without a thoroughly tested scenario, leading to warehouse operation failures and distorted inventory information.
- Integration problems with the e-commerce platform. Online orders were not properly transmitted to the WMS, causing widespread delays and order cancellations.
- Insufficient staff training. Warehouse and store employees were not trained to work with the new system, which further worsened the situation during peak demand periods.
- Poor timing of the implementation. Attempting to implement the system during the busiest season deprived the company of the opportunity to adapt to new processes.

As a result of these mistakes, the company suffered significant losses:

- Financial losses amounted to approximately $32 million;
- Up to 150 retail stores were closed;
- The company faced a wave of negative customer reviews, mass returns, and supply chain disruptions;
- The Chief Information Officer resigned.

This case serves as an example of how inadequate planning, rushed implementation, and lack of focus on the user experience can lead to failure even in large organizations with a high level of digital

maturity. It emphasizes the need for phased WMS implementation, thorough staff training, and choosing the optimal time for launch that avoids peak load periods.

Dynamic ROI (Return on Investment) is a metric that shows how the economic efficiency of implementing a WMS changes over time. Unlike the standard ROI, which shows the overall result, dynamic ROI takes into account:

- The adaptation period of the system: In the first months after implementation, efficiency may be low due to staff training.
- Growth in efficiency over time: As employees become more proficient with the system, its benefits increase.
- Changes in operational costs: System maintenance and updates also affect the overall
- profitability.

Fig. 4 shows the formula of ROI (Return Of Investments). ROI is a financial metric used to evaluate how efficient or profitable an investment is. It tells you how much profit or value you gained compared to what you spent.

$$ROI(t) = \frac{\sum_{i=1}^{t}(R_i - C_i - L_i) - I_0}{I_0} \times 100\%$$

where:

t — number of months since implementation.
Ri— income (or savings) in the i-th month due to WMS.
Ci — operating costs for WMS in the i-th month (maintenance, licenses).
Li — costs of personnel training in the i-th month (decreases over time).
I0 — total costs for WMS implementation (equipment, setup, initial license).

WMS is worth implementing if:

ROI > 30% within 1–2 years.
Warehouse area exceeds 5,000 m².
More than 50 users.

WMS is not justified if:

ROI < 20%, warehouse under 2,000 m², Fewer than 10 users,
Stable manual processes or limited budget.
Example of Applying the New Formula (Retail):
1. A company spends $50,000 on implementing a WMS.
2. During the first 3 months, employee training costs $5,000 per month. After that, these costs drop to $1,000 per month.
3. Revenue from warehouse process optimization starts at $5,000 in the first month and increases by 10% each month as employees improve their skills.
Operational costs for the WMS are $2,000 per month.
Calculation for the 6th month:

$$\text{ROI}(6) = \frac{38577 - 12000 - 18000 - 50000}{50000} \times 100\% = 82.8\%$$

Calculation for the 12th month:

$$ROI(12) = \frac{[\sum_{i=1}^{12} R_i] - (2000 \times 12) - (5000 \times 3 + 1000 \times 9) - 50000}{50000} \times 100\% = 13.36\%$$

5. PROSPECTS FOR WMS DEVELOPMENT

The evolution of technology and changing business needs directly influence the development of warehouse management systems (WMS). This chapter explores key trends shaping the future of warehouse management, along with emerging technologies that can significantly enhance WMS performance.

5.1. Artificial Intelligence and Machine Learning in WMS

Modern WMS solutions are gradually incorporating elements of artificial intelligence (AI) and machine learning (ML), which enable:

- **Optimization of warehouse processes** – AI algorithms analyze product movement data and suggest optimal storage and picking routes.
- **Demand forecasting** – using historical data, the system can predict future sales volumes and automatically adjust inventory levels.
- **Automatic error detection** – ML algorithms can detect data anomalies and prevent losses caused by human error.

AI and ML are already used in large logistics centers, but in the future, they may become the standard even for small and medium-sized warehouses.

5.2. Warehouse Robotics and Automation

Automated warehouse technologies are increasingly in demand. These include:

- **AGVs (Automated Guided Vehicles)** – robots that transport goods within the warehouse without human involvement.
- **Pick-by-robot and Pack-by-robot** – robotic arms that pick and pack orders.
- **Inventory drones** – unmanned aerial vehicles that scan barcodes or RFID tags to accelerate inventory counting.

WMS development in this direction will help minimize manual labor and improve accuracy in warehouse operations.

5.3. Cloud Technologies and SaaS Solutions

The growing popularity of cloud-based WMS is driven by convenience and cost-efficiency. In the future, we can expect:

- **Increased adoption of SaaS models** – companies are increasingly choosing subscription-based services over locally installed systems, reducing initial investment costs.
- **Hybrid cloud solutions** – combining local servers and cloud storage for a balance between security and accessibility.
- **Cloud analytics** – utilizing powerful servers for real-time analysis of large data volumes.

In the long run, cloud-based WMS may become the dominant standard for all types of warehouses.

5.4. Integration with IoT and 5G

The Internet of Things (IoT) plays a vital role in the evolution of WMS. Key development directions include:

- **Smart sensors and RFID tags** – real-time data transmission about the temperature, location, and condition of goods.
- **Full warehouse digitalization** – creating smart warehouse environments where every item movement is automatically tracked.
- **Use of 5G** – high-speed data transfer enables instant processing of large datasets and real-time equipment control without latency.

These technologies will greatly enhance the speed and accuracy of WMS operations.

5.5. Improved Interfaces and Usability

Future WMS systems will be more adaptive and user-friendly:

- **Voice control** – warehouse workers will be able to interact with the system without manual data entry.

- **Intuitive mobile applications** – warehouse management from any device without complex instructions.
- **Augmented reality (AR)** – AR glasses or tablets will display optimal movement routes or the exact location of goods.

These improvements will reduce training time and increase overall productivity.

5.6. Enhanced Cybersecurity

As warehouses become more digital, cybersecurity risks grow. Future WMS systems will actively implement:

- **Blockchain technologies** to protect data and prevent fraud.
- **Stronger authentication** methods such as biometrics and multi-factor verification.
- **Automated threat monitoring systems** to prevent hacks and data leaks.

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