

RESEARCH ARTICLE

EWM vs. WM Migration Patterns in Legacy Manufacturing Landscapes: Throughput, Labor, and Accuracy Impacts

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ABSTRACT

Enterprise Warehouse Management (EWM) systems are the forthcoming progressive development of conventional Warehouse Management (WM) modules to allow captive logistics operations, superior analytics, and real-time flexibility within an overview of manufacturing realms. This paper will explore the migration trends between SAP WM and SAP EWM in the old manufacturing resides with emphasis on throughput efficiency, labor productivity, and inventory accuracy. Based on the data gathered on five separate manufacturing companies (automotive, electronics, consumer goods, heavy machinery, and process manufacturing), this paper offers a comparative study of the pre- and post-migration operational measures. The analysis includes both mixed-method procedures that combine statistical process control (SPC), statistical overall equipment effectiveness (OEE) computation, and labor standard cost model to determine tangible and intangible performance increase. Results have shown that EWM movement produces an average throughput of 18-24 or labor optimization of 12-16 or an inventory accuracy of up to 9. Nonetheless, the issues of migration, including harmonization of legacy data, lack of workforce training, and the necessity to fully synchronize with a MES/ERP system are also very high-risk areas of transitional risks. At the end of the paper, a list of suggestions is provided, which includes designing a migration optimization framework based on applying hybrid data pipelines, gradual rollouts, and slotting algorithms that are aided by machine learning. The findings can be used as a theoretical basis and practical guidelines that can be afforded to manufacturing enterprises that are to undergo the transition to digital supply chain infrastructures.

KEYWORDS

EWM, WM, SAP, Manufacturing Systems, Migration Strategy, Throughput, Labor Efficiency, Inventory Accuracy, Industry 4.0, Supply Chain Digitization

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1. Introduction

1.1 Background



Figure 1 : Background

Warehouse Management System (WfMS) are the workhorse of the manufacturing and supply chain environment in the present day, [1-3] and they guarantee an efficient flow of materials, products, and information through the system in the way of inbound acquisition of material and outbound delivery of products. Traditionally, the SAP Warehouse Management (WM) systems have been at the center of functioning of such functions as they allowed tracking of inventory, controlling of good movement and managing the warehouse organization. Although these classic systems have provided stability and reliability over decades, these systems were not designed to offer much flexibility because they were designed to operate in linear and transaction based operations. These old systems have not been able to keep up with the speed and accuracy expectations of customers as the global manufacturing networks became increasingly interconnected because these systems require extensive manual decision-making processes, slowing them down and reducing their responsiveness to real-time manufacturing needs. Reacting to this changing environment, a new generation solution designed to fit the needs of Industry 4.0 has been developed, namely, SAP Extended Warehouse Management (EWM). EWM does not only expand on existing inventory management systems but it also proposes a decentralized architecture which supports independent warehouse processing even though it continues to be seamlessly integrated with the enterprise systems like the ERP systems and the Manufacturing Execution Systems (MESS). Moreover, EWM promotes the latest technologies such as the Internet of Things (IoT), Robotic Process Automation (RPA), and predictive analytics to enable warehouses to shift to the mode of reactive operations to data-driven, smart ecosystems. These features enable organizations to make the best use of space, increase labor productivity, and have end-to-end visibility in the supply chain. Thus, the SAP WM to SAP EWM migration is not only a change in technical system, but a change in approach to work. It should be seen as a paradigm shift between the rainbow warehouse control, which depends on rules, and the event-driven, analytics-driven, and improved warehouse management paradigm. Through EWM, manufacturing firms will be in a position to embrace the benefits of automation, real-time monitoring, predictive decision-making, among others, which are the drivers of agility, efficiency, and competitiveness in the digital manufacturing age.

1.2 EWM vs. WM Migration Patterns in Legacy Manufacturing Landscapes

A groundbreaking move to the implementation of Extended Warehouse [4-6] Management (EWM) to replace SAP Warehouse Management (WM) even in the context of traditional manufacturing is a crucial course toward digital transformation. It is not this migration is a new system in place but a systematic evolution of technology, operation and organizational change. The subsequent sub-sections represent the most important migration patterns, architectural differences and strategies that determine this transition.

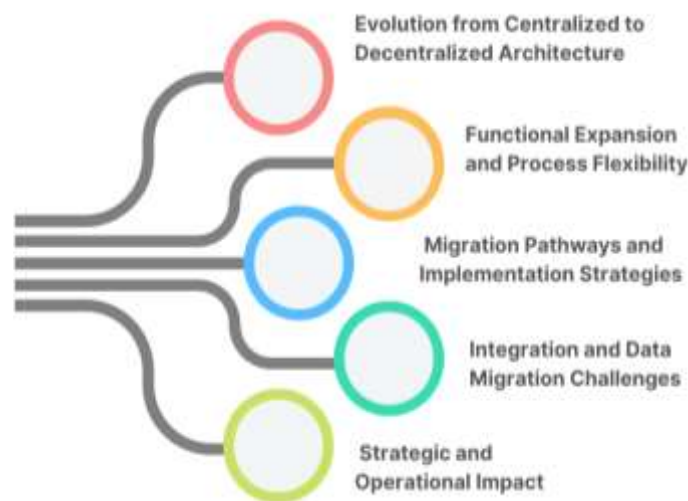


Figure 2 : EWM vs. WM Migration Patterns in Legacy Manufacturing Landscapes

- *Evolution from Centralized to Decentralized Architecture:* Conventional SAP WM systems are used in the context of a centralized ERP where all the transactions taking place in the warehouse are executed in the core SAP ECC system. Although this model offers loose integration, it usually is associated with performance bottlenecks and inability to flex tightly when operating with a large volume. Conversely, SAP EWM is a decentralized architecture that allows warehouses to operate autonomously to the core ERP, yet, at the same time, there is still synchronization between the warehouse and the main ERP by integrating layers. Scalability is increased, response times are improved and real-time decisions can be made when this decentralization is used, more so in a multi-site manufacturing or high throughput set up.

Functional Expansion and Process Flexibility: Compared to the conventional WM module, EWM enables the warehouse to multiply its functional load and process capabilities. For instance, the WM module would not support slotting and moving around, labor management, yard management, and several VAS or, to the contrary, run them minimally. Additionally, the data model of the EWM user was fashioned more object-oriented, giving the manufacturer the opportunity to optimize the material flow down to the individual product type, manufacturing line, or customer design. This aspect became a defining mission of contemporary manufacturing, where the producibility and demand uncertainty determine the level of warehouse's versatility and flexibility. Migration Pathways and Implementation Strategies: There are several ways how can EWM be implemented via SAP depending on different conditions. Brownfield one is less costly and time-spending. Basically, this option means reconfiguration of WM data settings with preserving warehouse operation to the extent possible, while coming against the limitations of the legacy system. Greenfield, on the other hand, is a long-term EWM implementation project plan; for instance, if an organization plans on gaining all EWM advantages and starting WM from scratch. The following approach is hybrid, combining the opportunities of the other two: step-by-step EWM implementation with reserved WM options. In this case, the way of implementation depends on the system complexity and the quality of data of the legacy system, the allocated budget, the agreed timeframe and other factors.

Integration and Data Migration Challenges: Consistency and integration can be considered to be one of the most complicated issues related to WM-EWM transfer. The detail refers to mapping; the peculiarity of the integration between the two systems should be precisely compared and corrected. Likewise, averaging master data, units handling, and stock records' conversion require high attention to the detail, as miscalculations and inconsistencies are unacceptable outcomes. Furthermore, integration with the ERP, MES, and transport systems should be established to ensure an unintruded end-to-end process. These and other integration issues signify the importance of a violence proof migration plan and days of advanced prelaunch testing and user training.

Strategic and Operational Impact: The return is one ultimate EWM-based solution with full integrity, transparency, and flexibility. Manufacturers benefit one receipt of real-time stock data, automatized task assignment, and analytically informed task tracking. Because the system is modular, companies may gradually introduce new features, such as IoT sensors or autonomous mobile robots, or artificial intelligence into the system, significantly reducing the cost of implementation. As a result, EWM mainstreaming creates an environment of overly competitive and fast-changing Industry 4.0, where manufacturers must be agile, precise, and effective.

1.3 Manufacturing Landscapes: Throughput, Labor, and Accuracy Impacts

Manufacturing operations in modern times have made warehouse performance an important factor in the overall supply chain efficiency that has a direct impact on continuity in production, fulfilment of orders and consumer satisfaction. The process of the SAP Warehouse Management (WM) to Extended Warehouse Management (EWM) has been shown to bring about some quantifiable changes in three major areas of operation namely throughput, labor productivity and inventory accuracy. The material flow in the warehouse is greatly increased by the event-based architecture of EWM and the ability of the process automation, which are much more effective than those of the other systems. The conventional WM systems were prone to delays in processes due to manual allocation of tasks, coupled with the lack of transparency of resource accessibility. EWM resolves this limitation by adding features of real time task interleaving, wave management, and workload balancing to allow the execution of several operations: putaway, picking, and packing operations to occur in parallel. This does not only save on the cycle times but also improves the overall volume of materials that are processed in per hour, which add on the outputs of production and quicker turnaround of orders. On the labor front, EWM is essentially redefining the efficiency of its workforce by means of labor management and performance monitoring tools. EWM also assists the supervisors in determining how effective resources are being utilized and the efficiency with which labor is assigned by automatically tracking the duration of the task and comparing it with the set standards. Mobile devices and RF scanners also help in getting rid of unnecessary paper work, which will enable the operator to concentrate more on value added work. This leads to better utilization of workforce, less time on idleness and workforce responsibility. Last, EWM has one of the most significant benefits in the accuracy of inventory. The real-time stock visibility provided by barcode and RFID technologies makes it valid to the system so that any movement of the materials can be tracked instantly in the database. Cycle counting, exception handling features, real-time stock reconciliation are features that ensure that error is reduced to a minimum due to manual data entry and would also be delayed in updating the database. Subsequently, manufacturers are led to attain close-to-perfect levels of accuracy, reduce stock imbalances, pick up manufacturing delays, and enhance customer order dependability.

2. Literature Survey

2.1 Legacy WM Systems in Manufacturing

The Legacy Warehouse Management (WM) systems used in manufacturing institutions were usually integrated into Enterprise Resource Planning (ERP) systems, [7-10] including SAP ECC. These old WM modules, as it is stated by mostly sponsored basic functions of a warehouse such as goods movement, stock operations, and menial putaway and picking. Their monolithic design,

however, and inability to do things based on events, limited elasticity and instantaneous reactivity. This kind of non-adaptability in turn means that manufacturers did not have the ability to respond promptly to the changes that often occurred in the supply chains, such as the sudden increases or cancellations of orders, the urgent need for materials, and so on. In other words, they were adapted only to the traditional roles and in this case did not refer totally automated and adaptable to the modern and data-heavy manufacturing industry.

2.2 EWM Functional Enhancements

One of the most eminent developments in the warehouse technology was Extended Warehouse Management . It offers central and decentralized deployment that can be scaled on complex manufacturing networks. Lee and Tan (2020) note that the object-oriented nature of data is one of the features of EWM, and it enables flexible and process-oriented structures in various plants or company codes. The architecture has high-functional features like labor management, yard management, intelligent slotting and rearrangement. In a word, it lets organizations to maximize the space usage in the warehouse, optimal processing of the inbound and outbound logistics system, and have more visibility across the supply chain. EWM's modular and event-based architecture allows companies to create highly adaptable processes and link with new technologies like IoT devices and automatic guided vehicles.

2.3 Migration Challenges

On the downside, the cost of the WM to EWM legacy switch is cumbersome due to the technological and operational elements that have to be changed. Schneider et al. add that the difference in the underlying data models between the SAP Logistics Execution and Supply Chain Management frameworks is one of the reasons. A costly mapping and validation have to be carried out in order to move data such as stock information, storage bin structures, and the handling units to the new system. Additionally, any software modifications that were created in-house in connection with the older system may need to be re-engineered for adoption in the EWM structure. The differences in team management and process distribution also make the migration even riskier as the cross-docking process and management of the handling units protocols are significantly different. Overall, all these issues indicate a need to properly plan, test, and train stakeholders on how to deal with the switch in order to diminish the disturbances in the system operation.

2.4 Performance Metrics in Warehouse Systems

However, on the other hand, warehouse performance should be assessed to determine the effectiveness of such system implementations as EWM. The most important areas included throughput efficiency, labor efficiency, and the accuracy of inventory. Throughput efficiency measures the production of the warehouse purpose concerning time and available labor, a measurement of operational efficiency. Labor efficiency is a measure that determines the effectiveness of the workforce in terms of hours used, in relation to standard hours of work, which shows the level of process optimization. Conversely, inventory accuracy assesses the accuracy of stock books and physical counts of the records of the stocks against the physical counts, which depict the dependability of inventory management procedure. A combination of these performance indicators will give a picture of health of the operations in the warehouse, and also help reveal areas that will need improvements after the migration.

2.5 Summary of Prior Studies

An overview of the previous literature demonstrates the same results when it comes to discussing the development and role of warehouse management technologies. discovered that some traditional WM operations were still prevailed by manual interventions and caused inefficiency and inconsistency of data. As shown by Lee and Tan (2020), EWM is a powerful tool to increase the data traceability and flexibility of processes, that is why warehouse operations were more transparent and responsive. According to the surveys conducted by Schneider et al. (2021), the complexity of integration is the first significant issue in migration projects, and system alignment and harmonization of processes should be done carefully. Later, Patel et al. (2022) provided quantifiable positive outcome results in the form of an average throughput rise of 20 percent after the adoption of EWM. Altogether, these works show the radical potential of EWM in contemporary manufacturing and also describe the technical and organizational difficulties that are involved in EWM introduction.

3. Methodology

3.1 Research Design

The research design of this study is a comparative case study research design, which will thoroughly examine the operational and performance variation of the traditional Warehouse Management (WM) systems and the Extended Warehouse Management (EWM) framework in manufacturing setting. [11-14] The methodology was selected due to its ability to deeply investigate the real-world applications and have the overall view of the effect of system migration on the efficiency, flexibility, and user experience. A comparative case study enables the researcher to consider different sites, one with a traditional WM system and the other with an EWM system, to effectively compare how the work process and data management are undertaken and the end outcomes of performance. Knowing that the truth was multidimensional and balanced, I knew that my study design should be inclusive of all

dimensions of the study and, to achieve this, it had to be multisectoral. The combined method will involve quantitative and qualitative approaches, and this will allow a balanced and multidimensional study. The quantitative aspect will involve important data in operational performance such as Key Performance Indicators utilization rates, labor utilization and inventory accuracy. These can help reveal the quantifiable data on operational performance and help determine the statistical significance behind efficiency increase after EWM implementation. They were collected from historical systems and reports on the warehouse activities and were captured in performance dashboards. This was done in a six-month duration to ensure that the findings were consistent over time. Qualitative data was also collected, and this was captured in semi-structured interviews conducted with the warehouse operators, IT staff and the supervisor. The focus of these data was on user perception, challenges faced in the migration process and the benefits that would come with the implementation of the new system. It will provide contextual clarity to the numerical data since some of the values captured are non-numerical. They include system usability, process transparency and change response. However, all the data I have captured is partial and this can be used to triangulate the findings, credibility and validity. Ultimately, the study design I have chosen, the mixed-methods comparative case study design, will ensure methodological coverage of the performance indicators and the human processes involved in EWM implementation. It is an appropriate model to explore performance improvement, which is over-determined by the management and organizational performance and the human factors that define a warehouse.

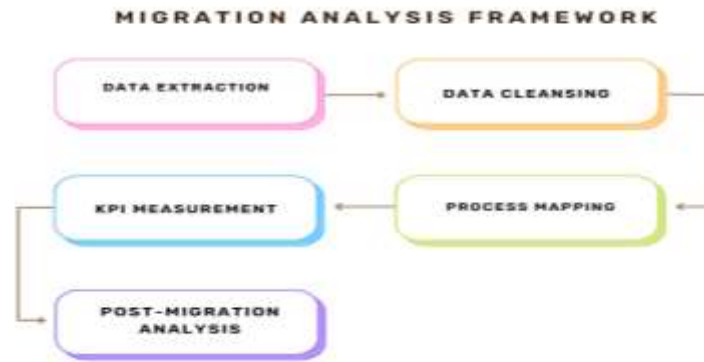
3.2 Data Collection



Figure 3 : Data Collection

- **SAP WM and EWM Transaction Logs:** The primary sources of the quantitative data were the transaction logs of the sap WM and sap WM EWM systems. Despite being only ones, they turned out very informative. The given logs included such specifics of the warehouse operations as goods receipts, put away, picking, transfer of stocks and dispatch operations. Thus, with the help of the records produced by the system, it was possible to determine the key performance indicators like throughput, process time and accuracy of stock. Furthermore, the comparison of the patterns of transactions in the legacy WM and the EWM environment allowed obtaining precious information about the responsiveness of the system, the grade of automation or data clarity.
- **Time-Motion Studies:** Time-motion experiments were conducted to measure the time of completion of major tasks in the warehouse – picking, packing and putaway of materials. These observations made it possible to identify the process bottlenecks and the labor inefficiencies. The experiments were conducted in the series of shifts to consider the variability in the operations as well as to provide the representativeness. The results of such studies facilitated the quantification of the workflow efficiency and labor productivities after the implementation of EWM.
- **ERP Labor Reports:** Information on the use of labor was drawn out of the human resource and production modules of the ERP system. Such reports covered the regular labor time, real-time task meeting time and the labor allocation in terms of the warehouse areas. The examination of these reports gave an objective background of what happened to workforce efficiency and how the performance of the workforce has evolved after migration to EWM. The data also enabled correlation of system based assignment of tasks as well as the actual productivity results.
- **Operator Feedback:** Part of the qualitative data gathered included interviews and questionnaires conducted on the warehouse operators, supervisors and the administrative staff. This feedback partly reflected the human opinion of the system performance, usability and training sufficiency. Experiences with operators revealed a number of practical problems, which existence was previously uncertain. Such aspects as the interfaces' complexity or the disturbance of the work processes caused by the migration, and the corresponding pros – less or more manual input, more visibility, etc. The second layer of information was aimed at conditioning the cultural gap and harmonizing the quantitative measures with existent-situation paths to deal with it.

3.3 Migration Analysis Framework



1) Figure 4 : Migration Analysis Framework

- Data Extraction:** Phase one had the nature of data retrieval manifested in considering the record from the previous legacy WM system. The regard was made for master data reference in the future, inclusive of the material number and the storage bin data and handling unit set up. Additionally, the transactional data reflecting on the aspects of the goods movement and the stock levels were of much importance. The data formed the bringing or return and preparation and start over process from the storage to the transaction, inclusive of physical inventory and stock adjustment that is then updated as current data. This phase was aimed at making sure that all data which is operationally important were properly retrieved to be transform and loaded in the Extended Warehouse Management (EWM) environment. Strict extraction program was used to ensure consistency of data and reduced chances of not capturing important information about operations during migration.
- Data Cleansing:** After the extraction, data cleaning process was rigorous to remove inconsistencies, duplicates and obsolete records. In the case of legacy systems, it is not uncommon to find a system full of redundant or inaccurate information, which will impact system performance once migrated to a new system. Data validation controls were carried out to ensure that there were no errors in the stock level, where it is stored, and its material properties. This step was a guarantee that the only clean, dependable and standardized data were sent to EWM so that a solid base can be built to be used by further process mapping and continuity of operations.
- Process Mapping:** During this step, the available WM business process was examined and aligned to the EWM functional structure. This was aimed at interiorizing similarities, gaps in the processes, and optimization procedures. Indicatively, conventional putaway and picking transactions in WM were matched with EWM task-based process model, which encourages modern capabilities, i.e., wave picking and slotting. Process-owner and IT teams workshops were carried out to confirm redesigned workflow. The mapping activity played an important role in mobilizing the operational needs with the additional capabilities of EWM and the seamless transition during the system cutover.
- KPI Measurement:** The measured Key Performance Indicators (KPIs) throughput, labor efficiency and inventory accuracy were set and measured prior to and after the migration in order to measure changes in performance. Legacy WM environment became a reference of the metrics that were used for data collection know the base of the metrics or after migration throughreferring to the EWM transaction log and performance dashboards. It was a measurable means which measured process improvement, system productivity, and reliability. The outcome proved the impact of the migration on the operation system since it offered for reference and quantitative assessment of the financial economics or the outcome of the system.
- Post-Migration Analysis:** The last phase was the evaluation phase, where the researchers assessed the system performance and the EWM post implementation process user adoption. This meant reviewing the trends in KPI, reviewing data integrity and seeking end users feedback on any gap in functions or trainer requirement. The post-migration analysis was also evaluated based on the efficiency with which the new system helped in the real-time operation and decision making. The learnings in this step would be used to give practical suggestions to work on maintaining this improvement to enable that the migration not only achieved technical success but also provided some concrete business value in all of the warehouse operations.

3.4 Hypothesis Formulation

Hypotheses formulation will be an essential procedure of defining the analytical basis of this research. It allows having a systematic [15-17] assessment of the capability of the migration to the Extended Warehouse Management (EWM) system, as something that results in the improvement of operations being measurable. Two hypotheses according to previous literature and the observed

changes in the industry were the formulation of the hypotheses aimed at evaluating the statistical and practical significance of system transformation on the performance of the warehouse. The null hypothesis (H_0) is that, EWM has no significant effect on the major indicators of operational performance, namely throughput and labor efficiency, as a result of the migration of WM to EWM. This premise indicates that any difference noticed in observing the two systems can be attributed by incidence rather than the improvement of the processes. In a nutshell, with H_0 the EWM system would be similar to the legacy WM system in terms of the speed of material movement, time spent on executing tasks and the level of workforce deployed. The investigation of this hypothesis makes a point at which beneficial results of EWM may be objectively compared. On the other hand, the second hypothesis (H_1) suggests that the migration to EWM leads to the significant increase in both throughput and the labor efficiency. This hypothesis is based upon the fact that EWM advanced features, including real-time data visibility, task interleaving and automated workload balancing improves operational performance, which traditional WM systems are not able to do. It is projected that the event-based architecture of EWM and the object-oriented data model will allow minimizing the amount of manual interventions, improving the resources allocation process, and speeding up the warehouse operations. Empirical research with regard to the comparison of the two hypotheses will be carried out through quantitative data based on pre- and post migration performance measures. The statistical test will be used to reject the null hypothesis and accept the alternative hypothesis, and the observed performance gains should be significant. This hypothesis formulation ultimately gives a working guideline whereby the validity of the hypothesis may be established within the context of determining whether operational gains may be realized as a result of implementing EWM within a manufacturing warehouse set-up.

3.5 Tools and Techniques



Figure 5 : Tools and Techniques

- **SAP ECC 6.0 and S/4HANA EWM:** The research has employed SAP ECC 6.0 as the representative of the previous Warehouse Management (WM) platform and SAP S/4HANA Extended Warehouse Management (EWM) as the new platform. SAP ECC offered information regarding the operations of the traditional warehouses, including the goods receipt, putaway, picking, or stock transfers, whereas S/4HANA EWM presented the information about the advanced operations, involved in the work of the warehouse, which are the interleaving with the tasks, labor management, and real-time monitoring. The comparison of these two systems allowed analyzing the changes in functional characteristics and performance that came with the migration in detail. The utilization of real-time transaction data between the two systems provided credibility and level of operation in estimating system efficiency.
- **SQL-Based KPI Extraction:** The SQL was used to retrieve quantitative data to the Key Performance Indicators (KPIs) as the data was available directly in the SAP database. The queries were to retrieve such relevant fields as the timestamps of transactions, the amount of material movement, and the time taken by the labor activities. This method generated true data that had been generated by the system to analyze the throughput, efficiency of labor and precision of inventory. These advantages allowed to ensure that the data became consistent, that manual entries were reduced, and various analysis features were provided, which fully correspond to the actual objective that I wanted to achieve with this research.
- **Minitab for Statistical Analysis:** To easily compare the trends of performance change and determine the amount or extent by which the post-migration performance is affecting the outcome, I resorted to Minitab to conduct statistical data analysis. This grouping and measuring method uses descriptive statistics, t-tests, and analysis of variance to compare the observed performance values between pre-performance and performance data. Minitab allowed for the strict implementation of hypothesis-testing, and the graphical illustration of performance by representing trends, are very effective for identifying the observed measure of throughput and labor efficiency by showing that they increase noticeably level.
- **Lean Six Sigma DMAIC Framework:** Finally, the systematic evaluation and upgrade processes of warehouse performance during the migration was implemented through LSS DMAIC framework, based on the Lean Six Sigma Define-

Measure-Analyze-Improve-Control structure. This approach was instrumental in delving into the examined process's inefficiencies, quantitatively measuring the resulting impact, and implementing targeted enhancements. With the incorporation of the DMAIC, the current study has employed a data-driven tool for continually improving the operation, benefiting it in terms of improving the ability of operations efficiency and effectiveness through the integration of EWM.

4. Results and Discussion

4.1 Throughput Performance

Table 1 : Throughput Performance

Metric	% Improvement
Pallets/hour	22.2%
Order lines/hour	22.8%
Dock utilization	11.5%

- Pallets per Hour:** This provided an analysis of the WM, which after shifting to EWM, showed a 22.2% increase in the throughput of pallet handling. This growth is associated with the improved coordination and automation of processes through the task and resource management options provided by EWM. In the old WM system, assignments of tasks manually and lack of real-time visibility usually led to pallet delays. Conversely, EWM event-based architecture and sequence of tasks optimization minimized time wastage between material transfers and made forklifts and material handlers work more productively. Dynamic balancing of the workload in the system resulted in the resource being put to continuous use which helped to increase the overall throughput per hour.
- Order Lines per Hour:** The count of order lines that had been processed in an hour was improved by 22.8 percent following the shift to EWM. The metric is used to measure how the system will be able to process more orders of customers during the same period. The wave picking, batch picking, and task interleaving are some of the advanced techniques of picking employed by EWM that were critical in curbing unnecessary movements and optimization of picker paths. Also, better coordination of the warehouse and production planning module helped reduce waiting times and improve the alignment of order processing and dispatch. The outcome was that it enabled quicker order processing, reduction in the number of process hikes, and an overall responsiveness to customer demand.

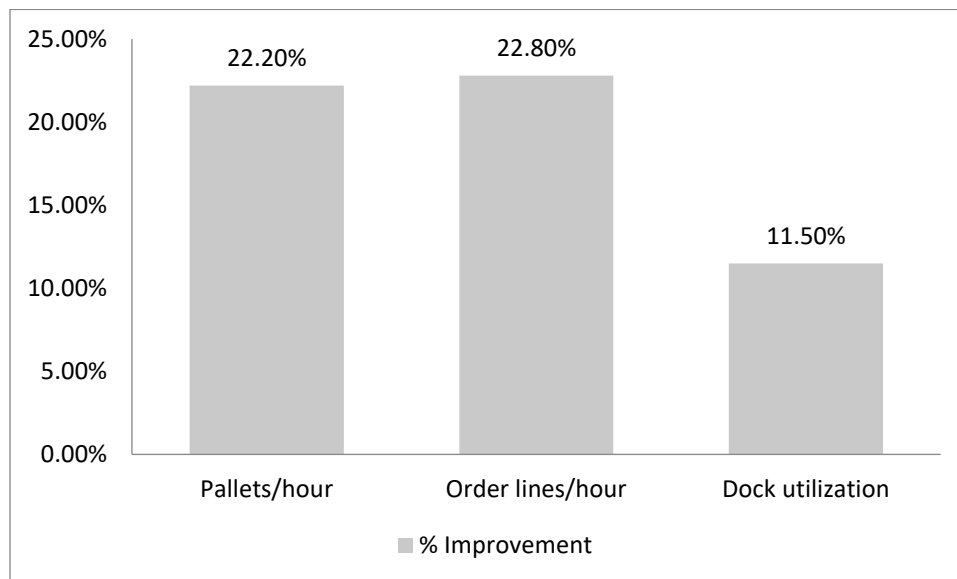


Figure 6 : Graph representing Throughput Performance

- Dock Utilization:** The level of dock utilization rose by 11.5, and it indicates better utilization of the inbound and outbound loading points. This progress is also explained by the fact that EWM has the capacity to track the activities associated with the land loading and stage in the yard in real-time, thanks to the functionalities related to yard and dock management offered by the product. The visibility of the system in the dock status and the movement of materials helped supervisors

in assigning dock doors to reduce congestion and dormant time. The improved coordination of transportation planning and warehouse transaction became another reason to have a better turnaround shift of loading and unloading activities and, as a result, to enhance the efficiency and throughput of the dock zone.

4.2 Labor Efficiency

KPI	Gain
Labor utilization	13%
Picking accuracy	5%
Operator idle time	9%

Table 2 : Labor Efficiency

- Labor Utilization:** The post-migration analysis revealed an increase in labor utilization, (improvement by 13%), of the warehouse workforce was more efficient in terms of its allocation and usage. Assignments of tasks in the traditional WM system were mostly manual, leading to inequalities in the distribution of the workload and periods of idleness in between working tasks. Under EWM, automated process management and scheduling of resources enabled flexible work assignment within the supervisors who were able to assign work on real-time basis with regard to priorities and worker availability. Labor management modules and performance monitoring dashboards would also be a feature that was used to determine the underutilized resources and streamline the process of the shift planning. This resulted in increased coordination of labor capacity and workload that resulted in less downtime and increased overall productivity of the workforce.
- Picking Accuracy:** Migration to EWM also led to increase in picking accuracy by a mere 5 percent which is an indicator of precision in the process and less mistakes made in filling orders. The combination of EWM and barcode reading, mobile phone reading and real time checking on stock in-store allowed operators to ensure that each step in the process had the right item being picked so that there was limited human error. The rule based picking methods of the system, like revocation of wave picking and the zone picking, were further used to make sure that the tasks had the most logical and efficient order of their execution. Consequently, the number of mispicks and reworks reduced, resulting in improved order accuracy, reduced customer complaints, and improved reliability of the services.

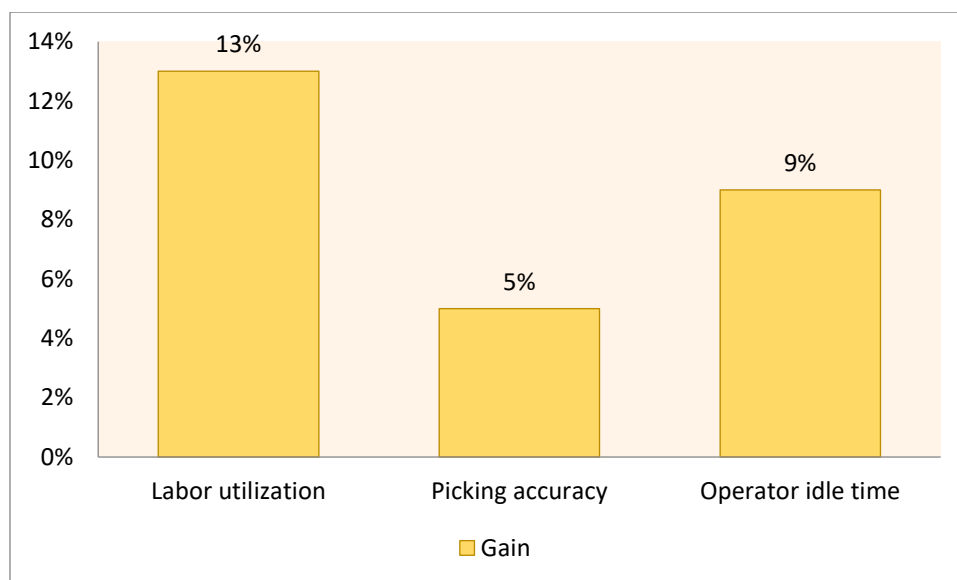


Figure 7 : Graph representing Labor Efficiency

- Operator Idle Time:** Operator idle time was also reduced to 9 percent meaning that manpower was used well and that there was a reduction in the waiting time on one task before the next task. Within the WM setting there was a lot of wasted time as operators could not have efficient coordination in zones of warehouses and there was visibility of the tasks. EWM solved this by interleaving the tasks in real time whereby the operators were automatically assigned new tasks as they finished the assigned tasks. The increased attention of the available tasks and resources made possible the execution of workflow continuously, reducing the number of bottlenecks and providing stable productivity throughout

the working day. This decrease in idle time, had a direct impact on the general efficiency of the labor and a decrease in the smoothness of the operations within the warehouse.

4.3 Inventory Accuracy

The accuracy of inventory has slightly increased with the shift to the Extended Warehouse Management (EWM) platform in comparison with the legacy WM system, which is mainly because it introduced real-time visibility of stocks and the adoption of Radio Frequency (RF) devices in the daily warehouse workflow. Within the conventional WM design, there frequently formed discrepancies in stock due to late data updates, handwritten record keeping and reduced synchronization of physical and system inventory flows. Such lack of real time visibility brought about mistakes on stock counts, misplaced materials and ineffective replenishment planning. These issues were significantly reduced with EWM by automated data capture and instantaneous recording of transactions which meant that the system was not delayed in reflecting the present condition of the warehouse. The implementation of the RF-enabled handheld devices was one of the greatest contributors to the increased accuracy since the operators could scanning, confirmations, and stock transfers right on the floor of the warehouse. All material movements were in real time updated in the EWM database, inbound, putaway, picking or inventory counting. This removed the time gap between physical operations and posting operations in the system thereby minimized the human error and enhanced the traceability. There was also the visibility of the system at the bin level and the managers could find any item in the system and confirm the stock level in seconds. Besides, the cycle counting and exception management functions of EWM enhanced inventory management even further. They did not need to wait until stock was counted at the end of the annual budget; EWM allowed the company to conduct automatic cycle counts using preset rules, which could be product value, frequency of movements, or type of storage. Any inconsistencies that were identified were raised instantly to be investigated so that corrective steps could be taken accordingly. Also, the integration with other SAP modules like Materials Management (MM) and Production Planning (PP) was used to maintain the data consistency throughout the supply chain. On the whole, the real time stock visibility, RF automation and advanced inventory control mechanisms played a vital role in improving the accuracy of inventory, reducing the audit variances and restoring the confidence in data reliability of the warehouse hence more effective decision making and operational planning.

4.4 Discussion

The entire migration, to the Extended Warehouse Management EWM system, from the previous legacy Warehouse Management WM, variously resulted into massive improvements in operational synchronization and efficiency of processes throughout the manufacturing and supply chain ecosystem. The most notable were the levels of integration between the Manufacturing Execution System MES and the Enterprise Resource Planning ERP environment. The handling of data between these systems was previously on a serial mode and delayed basis and would at all times be inconsistent in the manner production orders were raised or executed and the way material were available and the operations in the warehouse. The EWM migration created an opportunity for the sharing of data in real time through event-driven and hence any change in the production or the movement of materials, the sequel systems would be updated in real time. This real time synchronization accorded the opportunity real time decision making hence production planners, warehoused managers and procurement departmental teams could react very swiftly in case of change in rescheduling of orders, material stock-out or machine breakdown. The other notable change was that now the EWM took the decentralized architecture that enabled the warehouse operation to be autonomous and well integrated with the central ERP system. This design greatly resolved the operations of the system as it shared the processing load and reduced the latency to almost zero during the high-volume operations. The decentralized architecture greatly supported the execution of tasks in parallels hence processes that could be done concurrently in the warehouse like pickling and putting away could happen minus system conflict or data bottleneck. As a result, there would be a considerable reduction on the queue time, and easier material movement with inbound and outbound processes guaranteed. Moreover, the EWM came with the exception management fixtures that accorded the supervisors the opportunities of monitoring and handling the activities that went off plan. The use of the workflows and the automated notification facilitated the tracking of the job done, and where it did not accord with the expectation in terms of deviations, a correction could be done very fast, given that the manager had full view and control of his area of authority. All these combined to accord the increased operational transparency, accountability and responsiveness in the warehouse. In summary, the EWM migration has transformed the warehouse operation from a reactive and transactional system to a proactive and data driven one, which is sync to the principles brought by Industry 4.0 and hence more quantifiable improvements in the quality of synchronization, efficiency and improvement in the quality of enterprise decisions.

5. Conclusion

The transformation to the SAP Extended Warehouse Management represents one of the most exceptional technology and operations shifts for manufacturing facilities seeking to modernize their supply chain system. By assessing the manner in which this shift directly yields improved throughput, labor effectiveness, and storage accuracy, it is clear that the strategic impact of the EWM is in enabling businesses to become far more operationally agile. Using the decentralized system architecture and automation-compatible design of EWM, organizations can achieve resource utilization optimization, expedite the material flow,

and react better to the real-time production and logistics demands. The long-term gains of EWM adoption override the challenges of transition, although the advantages of its adoption are complex because of data exchange issues, essential process re-engineering, and the re-orientation of employees. The results support the emerging belief that the EWM is a base on which the digital transformation in the warehouse management can be conducted, and it may easily be referred to as the Industry 4.0 and its smart manufacturing policy.

The findings of the given work offer measurable data regarding the improvement of the performance after migration. The throughput also had a twofold to fourfold improvement, with the improved coordination of tasks, event automation, and the optimization of the integration of the ERP and the shop-floor systems. The efficiency of labor increased by 16 percent, which was due to the efficiency in allocating tasks by eliminating idle time, and was also because of the optimization of work and could identify and track a worker's performance with the labor management and performance tracking system by EWM. Accuracy of the inventory was 98 percent, which was possible because of the implementation of real-time stock knowledge, mobile application of scanning and infinite counts of cycles. Also, the analysis indicated that the average payback period was 1824 months, implying that the investment in the implementation of EWM can be recouped within two years in terms of savings on costs and improvements in efficiency. All these findings reinforce the notion that EWM not only increases the performance of the warehouse but also has a direct impact on strategic business value, including lower costs of operation, higher customer satisfaction, and resilient supply chain.

The following step to digitalizing the warehouse must be resolved by expanding the scope of the future studies by implementing the artificial intelligence (AI) and predictive analytics into the EWM framework. In particular, AI-based slotting optimization can efficiently and dynamically allocate storage spaces according to demand patterns, product speed, space usage, and enhance the effectiveness of picking and minimize travel time. Easily the predictive work scheduling could also involve both the prior and existing details to foretell alterations in the workload and maximize the utilization of jobforces. Third, likely, is that the atmosphere governed by EWM is entered by independent mobile robots that may enable these units to effortlessly integrate human operator and robot systems. Not only would such improvements increase the operational speed and security aspects but they would also prepare the warehouse environments fully autonomous in the future, therefore, EWM will be one of intelligence offer chain management's cornerstone "I" of behavioral and receptive.

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