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The Implementation of ERP and MES Systems as a Support to Industrial Management Systems

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Abstract

The improvement of the processes within the production system is the need of each company in order to enable better monitoring and control, as well as to provide all real-time information that are important for the decision-making process, in order to improve all processes and simultaneously control all elements of the process. Some of the systems that provide process monitoring are Enterprise Resources Planning-ERP and Manufacturing Execution Systems (MES) systems, but they are often not sufficiently integrated. The aim of this paper is to explore the needs of users of ERP and MES systems as well as the processes of implementation and integration of the new MES system into an already existing ERP system in a single automotive industry, with all the benefits for the users of the system that a company can achieve by implementing a well-implemented software solution.

Keywords: ERP system, MES system, management of the enterprise,

1. INTRODUCTION

In very dynamic conditions of production and operation of industrial production systems (enterprises), business success often depends on the minimal (usually seen as unimportant) savings in the duration of production (some of its phases), on the achieved product quality, or in terms of its exploitative reliability, or on small and even irrelevant differences in the price of products. In order to improve their business, companies are increasingly applying different business approaches within the production process itself (lean concept, reengineering, TQM, etc.) as well as various business information solutions that enable them to achieve processes and quality prospects and therefore better positioning on the global market.

When it comes to information solutions, there are currently more types of business information systems on the market, such as, for example, Customer Relationship Management (CRM), Supply Chain Management (SCM), Supplier Relationship Management (SRM), Corporate Performance Management (CPM), Enterprise Resource Planning (ERP), and Manufacturing Execution Systems (MES) systems [for more see 1-9]. The basic common feature of all business information systems is that they affect

employees, a large number of organization departments, and business processes of the organization in which they are implemented.

The aim of this paper is to explore the needs of automotive companies and companies from other manufacturing activities regarding the adequate model of computerized information system in industrial enterprises.

Although it is known that there is a whole range of modern information technologies and related resources for production, which have significant but not always and sufficiently exploited potential for industrial applications, the need for introducing MES systems in industrial enterprises is imposed if an ERP system is implemented, in order to improve all business processes. The paper is divided into two phases.

The first phase contains market research by applying questionnaires and interviews with regard to the application of the ERP and MES systems, and the second phase of the work is a presentation of new developed MES system integrated into the enterprise of an automotive industry, with an already entrenched ERP system by using the Value Stream Mapping tool for. This phase also includes a presentation of the results of the survey of attitudes of respondents who

used a newly developed MES system in a two-year study.

2. THEORETICAL BACKGROUND

Contemporary management relies on information as a necessary resource for developing other business resources. The information system is a system that, through formalized procedures, provides management at all levels with appropriate information based on data from internal and external sources, which enables

timely and effective decision-making related to planning, management, and control of activities in the domain of responsibility [10]. O'Brien defines the information system as follows: "The information system uses resources such as people, hardware, software, data and networks to capture, process, store, and control activities" [11]. The components, i.e. the information system resources, and their interrelationships are shown in Figure 1.

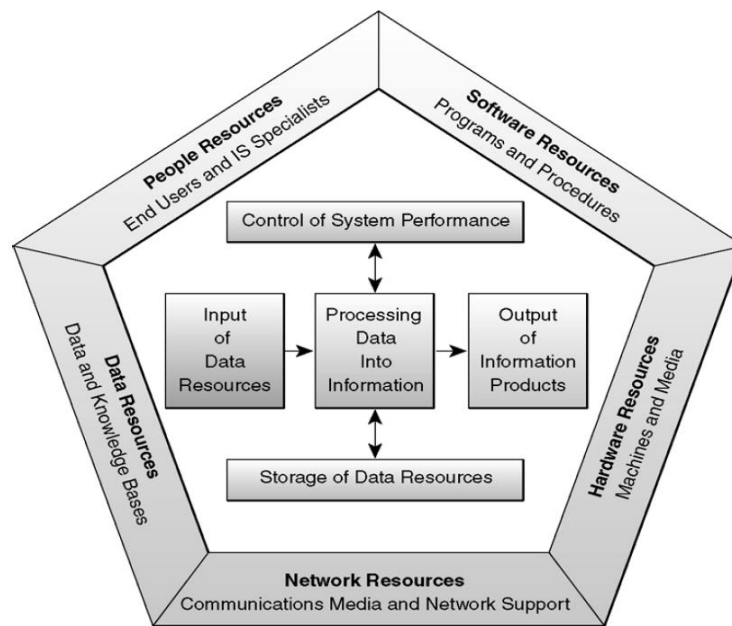


Figure 1. Components of the information system [11]

Management Information Systems (MIS) provide better planning, better decision-making and ultimately better results through the adequate distribution of information at different levels of management in the organization. MIS is an integrated, user - supported computer system for providing information to support operational management and decision making in an organization [12]. The faster development of information and communication technologies driven by the improvement of computer hardware and system software solutions has affected the application solutions used in organizations. At the same time, the business environment has become more and more complex, requiring more precise information and data flows within organizations, which would provide appropriate decisions at the right time, thus ensuring the competitive position of the organization on the market. By reviewing the available literature in the field of application of information technologies (which are supported by computers) in production technologies and its accompanying activities, there is an almost undivided understanding that integrated computer production is one of the few possible forms for achieving high values of the degree of effectiveness of industrial production, that it has a real foundation in the fast and stable development of information and

communication technologies and, given the sustainability of its development, it has a clear and certain future [13, 14]. Most researchers and authors agree that even in the far future, the integrated production will be the dominant form of production in general and that most of the production systems will function according to its basic principles [15, 16, 17]. The whole business of a company is carried out through business processes. Some authors have taken the view that "the process in each enterprise represents a set of interconnected activities with interactions, which transform the object (as its input) into a result (as its output), on the way that employees (people) certain procedural values, using the resources of the organization". The same authors state that the goals of the organizational system are implemented through the following business processes:

- profit increase;
- sales increase;
- reduction of production costs;
- increase of quality of products/services;
- market share increase and etc. [18].

In order to operate the processes within the company in the best possible way, it is necessary to provide an adequate flow of information within the company. ERP systems represent transactional systems that allow the

flow of information through various business and functional units in the organization [19, 20, 21] and they are designed to integrate business processes and functions and to be able to provide a more detailed view of the organization [19, 20, 21, 22].

The definitions of the ERP system vary according to the context, especially if different stakeholders' views are taken into account. Different stakeholders of the ERP system, depending on their position in the organization, will have completely different attitudes and experiences with the ERP system [23]. Below this part of the text, there are some of the definitions that can be found most frequently in the literature.

Deloitte Consulting defines the ERP system in its report published in 1998 as a business software package that allows organizations to:

- automate and integrate most of their business processes;
- share common data and good practices throughout the organization;
- create and access information in real time [24].

Davenport defines the ERP system as a "packaged software product that an organization can purchase as a finished product ("of-the-shelf") in order to integrate and share its information and related business processes within functional areas and between them" [19]. Its definition emphasizes the integration, set up by the ERP system, between different organizational units, basically functional areas within the organization such as finance, marketing, procurement, supplies, sales and distribution, human resource planning, etc. Gable defines the ERP system as a comprehensive software solution - a package that seeks to integrate a complete range of business processes and functions, in order to present a complete overview of business from unified information communication architecture [25]. In a slightly different way, Rosemann defines the ERP system as flexible, standard application software that includes integrated business solutions for basic processes (e.g. production planning and warehouse management) and the main administrative functions of the organization (e.g. accounting and human resources management) [26]. Al-Mashari and Al-Mudimigh define the ERP system as information communication technologies and infrastructure that allows the flow of information within the organization and communication with suppliers and other members of the supply chain [27].

Davenport, Harris, Cantrell, Laframboise and Reyes point out that the ERP system combines business processes in the organization and represents a way of doing business rather than just a software package [28, 29] while Kumar and Hillsgersberg define ERP systems as "upgradeable and interchangeable information systems packages that provide integration of information from all functional parts of an organization" [30]. Wallace and Kremzar define ERP systems as "a wide range of organizational management tools that balance supply and demand and allow suppliers and consumers to be integrated into a single supply chain by using proven business decision-making processes

and provide a high level of functional integration between sales, marketing, manufacturing, logistics, procurement, accounting and finance, the development of new products and human resources, thus enabling employees to do their jobs with higher productivity, lower costs and stocks, and higher consumer orientation" [31]. This definition of the ERP system is considered to be the most complete definition of the ERP system in academic literature.

Shehab et al. support Davenport's perspective and emphasize the importance of integrating the organization, arguing that the ERP system is more than just a software that integrates functional areas within the organization [32]. This claim is popular with most researchers who generally observe and define the ERP system based on its ability to integrate previously separate, completely independent information systems. Umble et al. claim that purchasing an ERP software package is much more than the purchase of software itself, but it implies the download of the best practices for many of business processes of the organization that the manufacturer has incorporated into the ERP system [33]. ERP systems include best practices that are supposed to be the best way of doing business [34, 35, 36]. These "best practices" are the basic assumptions and beliefs embedded in the ERP system by the manufacturer.

According to the literature review, there are a very large number of definitions of what the ERP system actually represents. By summarizing the definitions, probably the simplest definition of the ERP system, given by Tadjer: "One database, one application and a unique interface within the entire organization" [37] while the most widely accepted and used definition of ERP system is the definition stated by the American Production and Inventory Control Society - APICS; according to which the ERP system is "framework for organizing, defining, and standardizing the business processes necessary to effectively plan and control an organization so the organization can use its internal knowledge to seek external advantage. [38]"

In addition to the ERP system definition, understanding the history and evolution of the ERP system is essential for understanding its importance for the business of organizations [see 39, 40]. In many respects, the ERP system has been designed to overcome the operational problems experienced by the organization using previous information systems. Business (information) systems date from the early fifties of the twentieth century. This period coincides with the introduction of computers into the business of organizations, when the first applicative solutions began to appear. At that time, applications were used to automate processes such as book-keeping and inventory management. In the 1960s, the use was extended to Inventory Control Systems (ICS) and Bill-of-Material (BOM), gradually becoming standardized and evolving into the Material Requirements Planning System (MRP).

Enterprise Resource Planning - ERP systems have been promoted by the American Production and Inventory Control Society - APICS since 1980 and can be considered as the next generation of MRP II

systems. They connect the functionality of the MRP II system with other areas of application such as quality, maintenance, marketing, accounting, etc. The ERP system is the first approach that connects business and IT concepts in an integrated manner [41]. The rapid development of the ERP system began in the early 1990s, and at that time they were exclusively dedicated to the large organizations. ERP systems, as extremely expensive and complex systems, differed from other information systems because they represented ready-made software packages that were to some extent adapted to the needs of an organization. Adapting to the specific needs of an organization was made possible by the fact that, unlike traditional information systems, ERP systems consisted of modules that were adapted to potential changes and upgrades.

The overall resources of the organization could be integrated through the ERP system so that the ERP system is the next logical level of sophistication in the evolution of a number of computer tools for business support. The ERP system is used not only in production organizations but in every organization that wants to improve competitiveness in the most efficient way by using all of its resources, including information [40, 42]. Modern ERP systems (solutions) pretend to be complete solutions for the given purpose (planning and "full control" of business resources). ERP systems apply a unique set of resource planning tools across the organization, enabling the integration of all sectors of the organization in real time and linking suppliers and consumers into a single supply chain. Acceptance of the ERP system within large production organizations requires the integration of work practices (habits) and information systems [19, 43].

Organizations around the world are implementing ERP systems for various reasons, including, inter alia,

replacing old legacy systems, standardizing the system and faster processing of information in order to gain a strategic advantage [19, 20, 44, 45, 46]. ERP systems are costly to implement and the process itself is often followed by risks. Despite the difficulties encountered by organizations in implementing ERP systems [44], software packages continue to expand globally [45, 46]. Understanding the benefits of the ERP system and the ability to quantify these benefits are becoming crucial for executives who must justify the significant costs and operational impacts of the system on the organization [47]. Benefits are usually not realized immediately, therefore they are not widely accepted when putting the system into operation, but it often takes months or years to fully integrate all the changes brought by the new system [48, 49].

Often, organizations try to make their budgets as small as possible and reduce costs in order to avoid a reduction in the number of employees. Due to the costs, investing in a new business information system or just upgrading an existing IS is a very difficult decision and a major challenge for any organization. Investments in technology, as well as all other investments, arise from careful consideration of the analysis and assessment [50]. MES systems are used to monitor and produce documentation of the entire production cycle of the product itself (from raw material to final product).

The MES system provides real-time information that helps to make decisions in order to improve production processes and enables control over all elements of the production process [51, 52].

MES systems can be understood as intermediate in IS architecture, on the one hand, Enterprise Resource Planning (ERP) and Supervisory Control and Data Acquisition (SCADA) or process control system, Figure 2.

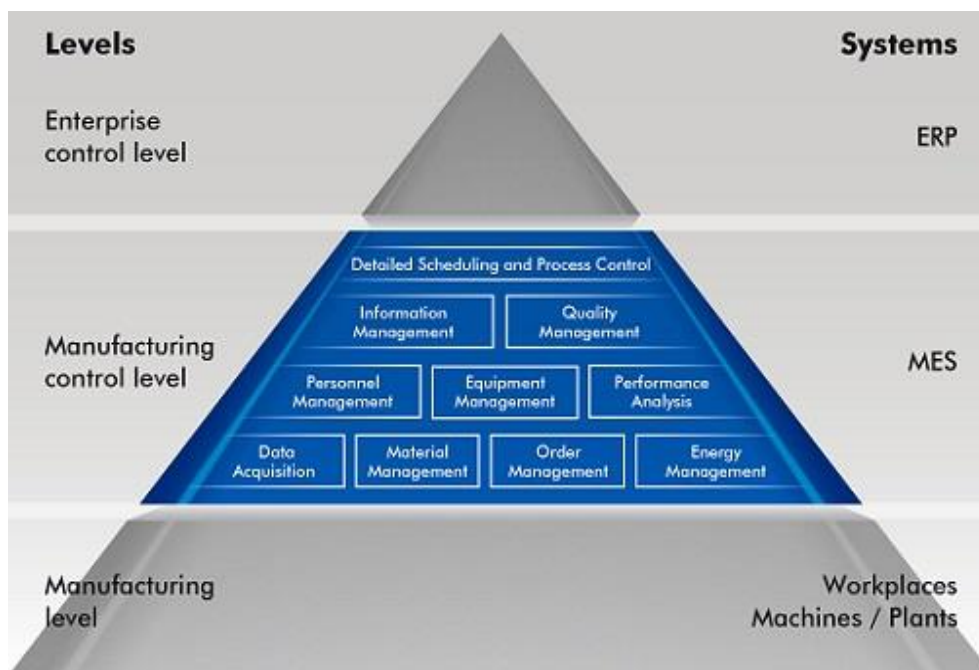


Figure 2. MES System – 5600 VDI (source: MPDV and VDI – Association of German Engineers)

As already mentioned, the MES system is functioning based on the vertical and horizontal principles. Vertical principle provides all relevant data, i.e. control of all aspects of production/confirmation (Figure 3a) in real time in relation to:

- Current capacities (machines, tools, materials, and employees) and capacity utilization;
- Real-time status and progress of production processes;
- Remaining processing time;
- Backlogs;
- Cycle time/steps;
- Reservation of capacities (machinery, tools, materials, and employees);
- Conflict resolution (deadlines, tools, machines, materials, etc.);

- Performance data of the industrial system.

Horizontal integration with the MES system (Figure 3b) covers the entire production process in industrial enterprises without additional applications [53]. The horizontal principle is integrated:

- Acquisition of production data and orders;
- Collection and processing the data of machines and employees;
- Actual production planning;
- Quality;
- Maintenance;
- Warehouse/Logistics;
- Human Resources;
- Information on other processes;
- DNC data.

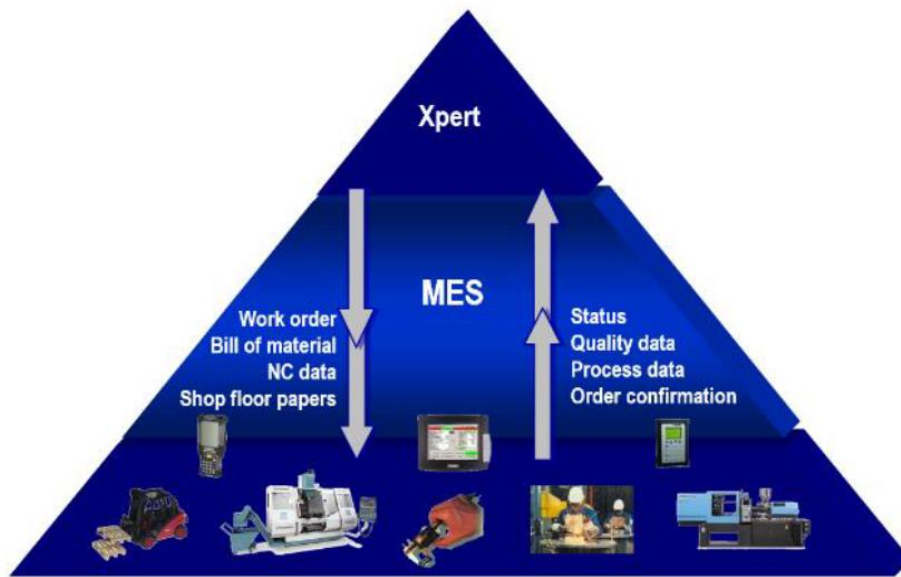


Figure 3a. Vertical integration through the implementation of the MES system

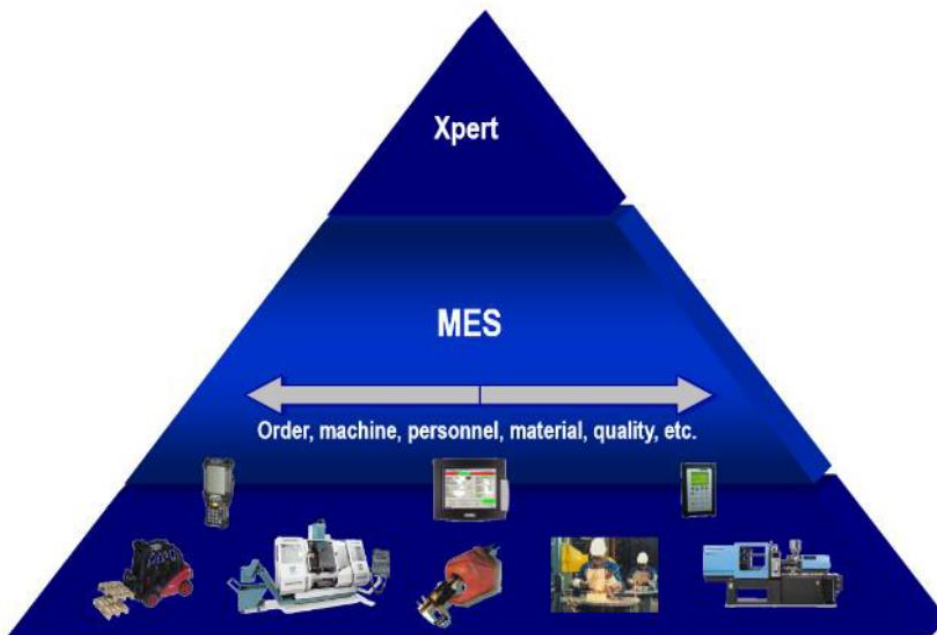


Figure 3b. Horizontal integration through the implementation of the MES system

3. ANALYSIS OF THE RESULTS

As already stated, the paper is divided into two parts. The first part of the paper was aimed at researching the needs and the usage of the adequate model of integrated computer information system in industrial enterprises. The research hypothesis of the first part of the work can be set up as:

There is a whole range of modern information technologies and related resources for work in production and for production that has significant (and not always sufficiently exploited) potential of application in industrial enterprises, and on that basis, there is a need for the introduction of MES systems in industrial enterprises if there is an ERP system implemented, in order to improve all business processes.

In order to confirm the research hypothesis, the research in the work was carried out with the task of analyzing the market of ERP and MES systems in small and medium-sized enterprises, and in terms of perceiving attitudes of experts and practitioners. We contacted the representatives, manufacturers, and users of the ERP systems and MES systems, as well as consulting companies dealing with the implementation of ERP and MES solutions.

Respondents who were involved in the implementation projects of the ERP and MES system in their organizations filled in the questionnaires on the basis of which the results were obtained. A questionnaire survey was conducted in a two-year study that covered the questionnaire and interviews with respondents. The questionnaire included a survey of market position views on the ERP and MES systems.

The questionnaire was forwarded to 75 addresses of which 34 questionnaires (valid ones) were filled correctly. On the basis of the conducted questionnaire, it was established that companies in the territory of the Republic of Serbia use a whole series of:

- **ERP systems:** SAP (*BusinessOne, AiO, R/3*), ORACLE - *People Soft*; *Infor (Xpert, XPPS)*, BAAN, *Microsoft Dynamics systems: NAV (Navision), AX (Axapta), GP (Great Plains), SL (Solomon); PULLS™*; etc., and
- **MES systems:** *Gfos.MES – GFOS, prisma – IBS, HYDRA – mpdv, SYNCOS MES – SYNCOS, cronetwork – industrie informatik, GRP, GUARDUS MES, PROXIA MES – PROXIA*, etc.

Based on the conducted research, 97% of the respondents use ERP system, and 70% of the respondents use MES systems.

In addition to researching the application of the ERP and MES systems, it is possible to conclude that all respondents point to several key elements, and above all that the benefit of using the MES system in selected companies from the perspective of end users and

business depends on the level of integration of the implemented MES solution with the existing ERP system. In the concrete research, the respondents pointed out that currently there is no good implementation and integration of the ERP and MES systems in companies they operate, and this aspect from their point of view significantly influences the quality of monitoring of the production cycle of products in real time, the possibility of timely informing employees, as well as the inability of enterprise response to sudden changes and continuous quality assurance (Figure 4).

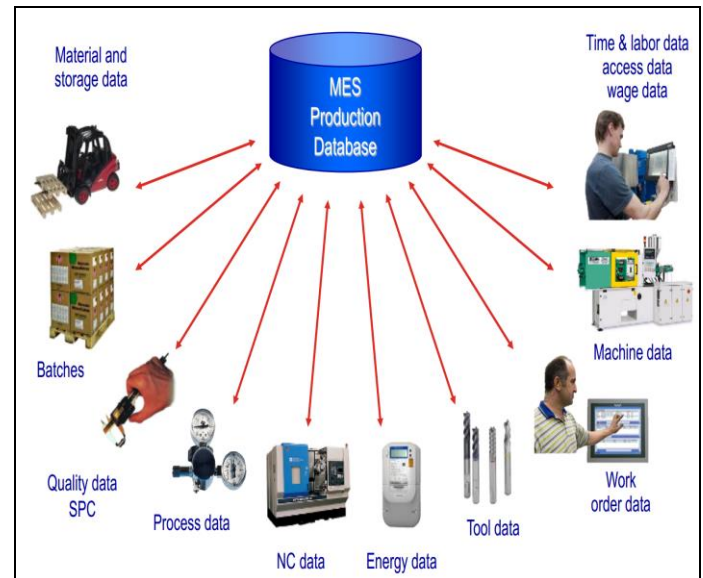


Figure 4. MES - Centralized data collection

On the basis of the obtained data, the implementation of the MES system in the automobile industry company with over 2,100 employees has started.

The selected industrial company did not implement the MES system but only the ERP system, and it was very important to introduce the MES system since the industrial company operates in the automotive industry according to all existing standards.

The newly installed MES system is fully integrated into the pre-implemented ERP system (Infor Xpert) that supported most of the operations of each ERP system but at the level of the company's management, located in multiple production locations without detailed monitoring of all processes in each of these locations.

Prior to the development and implementation of the MES software solution, the value stream mapping was done in order to see the real system itself, which was used as the basis for detecting the biggest problems, i.e. the locations that are necessary to focus in the improvement process (by using the MES system).

After the implementation of the MES software solution, the second value stream mapping was made in order to review the improved real system - a new current state (Figure 3).

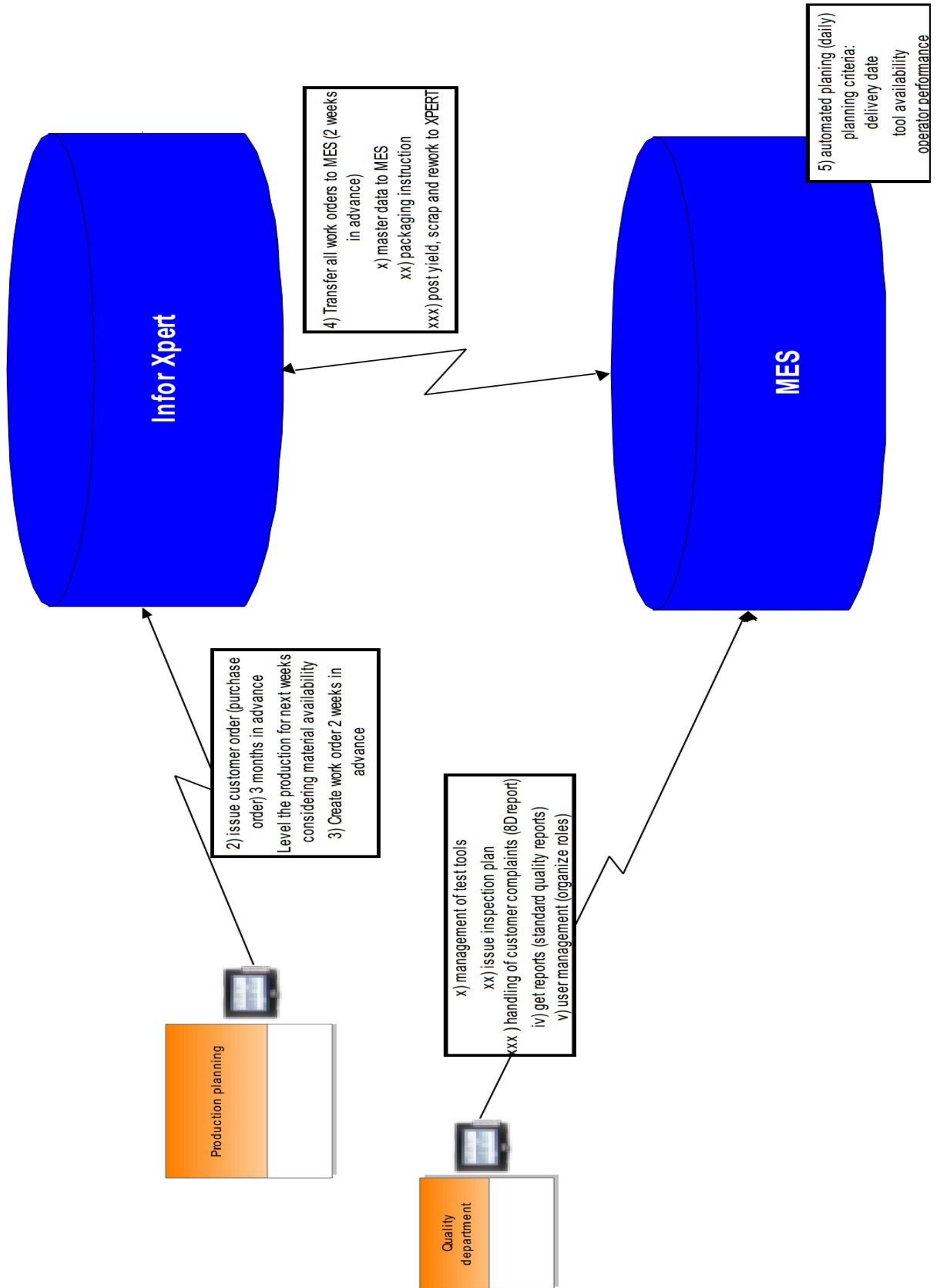


Figure 3. Part of Value Stream Mapping of the MES system implementation

After the integration of the new MES system in the existing ERP system was carried out, another questionnaire, with the aim of exploring the experience of working with the implemented software solution, was conducted. A questionnaire survey was performed in a two-year study and a total of 57 complete responses (valid questionnaires) were collected. Based on the data analyzed, it was found that the benefits from the usage of new MES system in selected companies from the perspective of end users depends on the level of integration of MES solutions implemented with the existing ERP system.

The benefits obtained with the implemented MES system are reflected primarily through better information for employees, efficient design, production planning, and quality assurance, enabling organizations to respond quickly to changes, improvement of productivity, competitiveness, and creation of strategic advantage. According to the research, 92.98% of the subjects confirmed that the implementation of the software solution MES increases the competitiveness of the enterprise itself, ensures the creation of strategic advantages on the market while simultaneously using the Lean concept method. The improvements are mostly reflected in the following segments:

- production planning and monitoring;
- production capacity planning;
- human resource planning and training;
- improvement of product quality and production processes;
- improvement of maintenance;
- easier performance analysis / KPI,

while 7.02% of respondents consider that implementation of the MES system in their opinion does not contribute to the benefit of the company. It has also been established that the implementation of the MES system in the industrial enterprise provides benefits in terms of:

- defining a clear structure of production planning and production capacity;
- reduction of documentation through papers to the minimum;
- easier performance monitoring / KPI;
- improved maintenance / preventive maintenance system;
- improved employee training process;
- real-time communication with the existing ERP system;
- improves the participation of employees, etc.

4. CONCLUSION

The need for continual improvement is the imperative for each enterprise in order to maintain its competitiveness in an increasingly changing market environment. Based on the conducted research, the need for creating the MES software solution was established, which was implemented in the pre-set ERP system within the company.

The implementation of the ERP system in industrial enterprises, based on user research, indicates that as an independent system is not sufficient, and that the implementation of the MES system in the ERP system should be implemented, thus providing information in real time and assisting in making decisions in order to improve all process systems with simultaneous control over all elements of the production process.

Also, based on the conducted research, it has been established that there are standard ERP systems and MES systems with their modules, but each industrial company has the option of creating its own software solution with the help of modern methods and techniques in the field of information systems design in order to ensure monitoring of all processes in small and medium industrial enterprises. For the needs of the research, a two-year study of the implementation of the MES system in the ERP system was carried out in one industrial enterprise from the automotive sector, with the indicated benefits. It is very important to note that when introducing the MES system, it is necessary to create a continuous learning process.

Often it happens that after the introduction of the MES system companies often resort to reducing the financial resources or the number of employees they will send in training. However, when employees are not taken into account, all the specifics of the implemented solution and all the benefits of the software will disappear over time, due to inadequate training or natural resistance to change.

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Implementacija PPR i SIP sistema kao podrška sistemu menadžmenta u industriji

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Apstrakt

Poboljšanje procesa unutar proizvodnog sistema je potreba svake kompanije da omogući bolji nadzor i kontrolu, kao i da obezbedi sve informacije u realnom vremenu koje su važne za proces donošenja odluka, kako bi se poboljšali svi procesi uz simultanu kontrolu svih elemenata tih procesa. Neki od sistema koji obezbeđuju praćenje procesa su Sistemi za planiranje poslovnih resursa (PPR) i Sistem izvršenja proizvodnje (SIP), ali oni često nisu dovoljno integrisani. Cilj ovog rada je da istraži potrebe korisnika PPR i SIP sistema, kao i procese implementacije i integracije novog SIP sistema u već postojeći PPR sistem u jednoj automobilskoj industriji, uz sve prednosti za korisnike sistema koji kompanija može postići primenom dobro implementiranog softverskog rešenja.

Ključne reči: PPR sistem, SIP sistem, upravljanje preduzećem