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Logistic-information system based on object-oriented approach

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Abstract: The article deals with the issue of creating an information system through an object-oriented approach, which is suitable for ensuring an efficient and properly functioning logistics network. An object-oriented approach to the creation of a business information system pays attention to a set of cooperating objects and reacts more flexibly to events in the environment. The main effort within the object-oriented approach is the reuse of created objects for a new system, which significantly contributes to shortening the development of new systems. For this fact and based on practical experience, the mentioned approach was chosen by the authors of the article. The overall design and functionality of the information system were influenced by the strategic direction of the company, which was also necessary to consider when preparing the article. In the end, a comparison of specific and object-oriented approaches to the creation of information systems for the company is processed.

1 Introduction

Managing business processes using information support means connecting and cooperating with people in a virtual environment to achieve the desired result in the highest possible quality. The connection of PLM/Product Lifecycle Management and ERP/Enterprice Resoure Planning enables selected work processes (repetitive or based on a common algorithm of solutions) to be automated and thus speed up their course, to improve its quality by reducing the error rate and to make the processing of large volumes of data more efficient. Such a change in the way business processes are managed makes it possible to simplify the implementation of even the most complex processes, to ensure the correct distribution of tasks, the correct distribution of data to the right person and at the right time [1-3].

While increasing competitiveness and customer orientation of services in the form of added product value, logistics has undergone major modernization periods. The role of logistics is to integrate, regulate and generally control the material flow, including semi-finished and finished parts. By monitoring and reacting to information in the course of simple logistics operations (transport, packaging handling, etc.), it optimizes their conduct in order to reduce costs and satisfy customer requirements. Logistics does not stand out as a separate process but interferes with every area of the company's functions in accordance with the established company strategy. Logistics represents a complex system of management, monitoring, and regulation of company flows.

Logistics generally has a clearly set objective, which is to reduce the costs associated with logistics and to streamline the use of its activities. The result of having such an objective is an increase in company profit over logistics costs. Therefore, long-term strategic planning also includes improvements in operational areas such as the supply chain. Just as it is difficult to characterize logistics in general terms, it is equally difficult to determine the division of logistics. In terms of the extent of its complexity, applicability and arrangement in practice, it will be used a division into three main groups: supply logistics (also called procurement logistics), production logistics and distribution logistics.

1.1 Object-oriented approach to the establishment of business information systems

The first step of the object-oriented approach to the establishment of business information systems is the identification of all objects of interest, as well as the knowledge of relations between these objects. Every object represents a structure that has a defined identity, behaviour, and state. Objects can be material matters, interactions, various events, etc. Object identity ensures the differentiation of an object from other objects, i.e. its identification. Object behaviour is the ability of an object to react to environmental events at state changes (Figure 1). Object state is defined by persistent properties and their values throughout the life of the object [4-7].

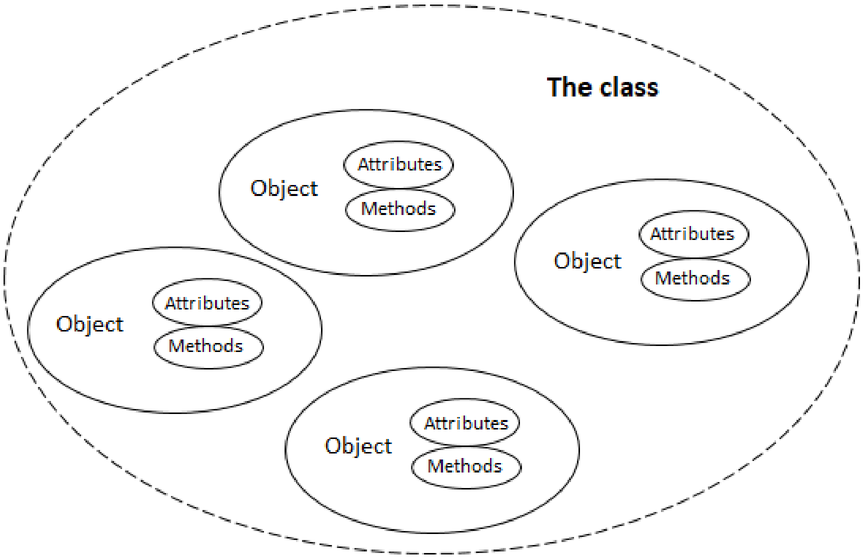

Figure 1 Structure of an object-oriented approach

Basic principles of the object-oriented approach to business information systems include [1-3,8,9]:

- Encapsulation – a state when objects keep their status inside classes, while other objects do not have access to this status. Objects manage their status through methods. As long as there is a requirement for communication with an object, this communication is possible only through available methods, while the object's status cannot be changed or affected.
- Abstraction – within the object-oriented approach, in many cases, extremely large programs are generated. Implementation of the abstraction feature ensures that internal implementation details are hidden, while only operations relevant to other objects are displayed.
- Heredity – ensures the principle of repeated use within the object-oriented principle of business information system establishment. In the case of heredity, a subclass is generated by derivation from another class, i.e. mother class. In this way, hierarchy arises. The created subclass takes over all methods and objects from the mother class and can implement its unique elements.
- Polymorphism – enables the use of the subclass in the same way as the mother class is worked with, while the subclass keeps its unique characteristic. It emphasizes the most frequently used methods which can be consequently implemented by sub-classes in a suitable way. In case of polymorphism, while applying one method, different behaviour or reaction of multiple objects might occur.
- Within the object-oriented approach to the creation of information systems, a great number of techniques and methodologies is developed nowadays. These techniques and methodologies are dedicated to modelling of future software solutions. Their development is, however, based on object-oriented design and object modelling technique.

In object-oriented programming, objects are grouped into classes that generalize objects according to similar or identical properties and behaviour models. An object class is characterized by certain attributes which are common to all objects in the class and by methods that represent object behaviour. A class generally represents a pattern for the creation of a specific object.

1.2 Comparison of object-oriented approach to the creation of information systems of the company

Based on the foregoing analysis of theoretical basis for object-oriented approaches, it is possible to state the following [1-3,8,9]:

- A typical feature of a structured approach is the segregation of data structures into a single module and processes into another module. In the case of the object-oriented approach, a combination of data and processes applies. It can therefore be concluded that by using the object-oriented approach a greater consensus between reality and business information system can be achieved.
- The model within the object-oriented approach enables an analysis of internal relations between objects, which leads to the design and establishment of the information system precisely according to the requirements of the future user.
- Ready software applications within the object-oriented approach can be used repeatedly ability, which shortens the development time of the future information system.
- In comparison to the structured approach, the object-oriented approach provides possibilities for more flexible adaptation of the ready system to changes. This enables quicker reactions to user requirements.

- The structured approach, considering its concept, glossary, and expressions, belongs exclusively to the field of information technologies. The object-oriented approach is a more comprehensible tool that is suitable for the establishment of business information systems even by the general public. Through the involvement of the general public in information systems it is possible to avoid mistakes that result from a misunderstanding between the author or requirements and the programmer.
- In comparison to the structured approach, the object-oriented approach requires greater computing time and memory space.

The implementation stage or the stage of business information system integration, in our case the Kanban system, follows the design stage. The above-stated comparison shows that for these purposes and under existing conditions it is more appropriate to use the object-oriented approach with its methods and tools.

1.3 Architecture of Integrated Information Systems

The architecture of integrated information systems represents a hardware and software infrastructure that offers tools for process analysis, creates a holistic view of the creation and management of processes and the flow of values. It is a general methodological framework and tools for modelling business processes in the PLM interface, with ERP support. If the main task of a PLM solution is product innovation and development, monitoring and management of information and product configurations throughout their life cycle, management of production processes, and cooperation between engineering departments, then we can say that PLM is data-driven [10-14].

In contrast to business information systems that manage finances, contracts, production order processes, production planning, logistics, and warehouse management, here we can say that information systems are transactionally managed. PLM and ERP play different, complementary roles in product innovation and execution, and therefore their mutual integration helps companies to be more efficient in their activities related to the development and management of the manufacturing portfolio of products. An example of this cooperation is attached in Figure 2, where we can see the mutual sharing of information about the structure of products, items, changes, production information, technological procedures, etc. The construction of such infrastructure will be provided by the company:

- digitize, optimize, and standardize your processes,
- reduce costs by executing processes with less manual effort,
- minimize cycle times with process automation,
- improve productivity for all stakeholders with the right information at the right time,
- ensure consistency and completeness by standardizing best practices.

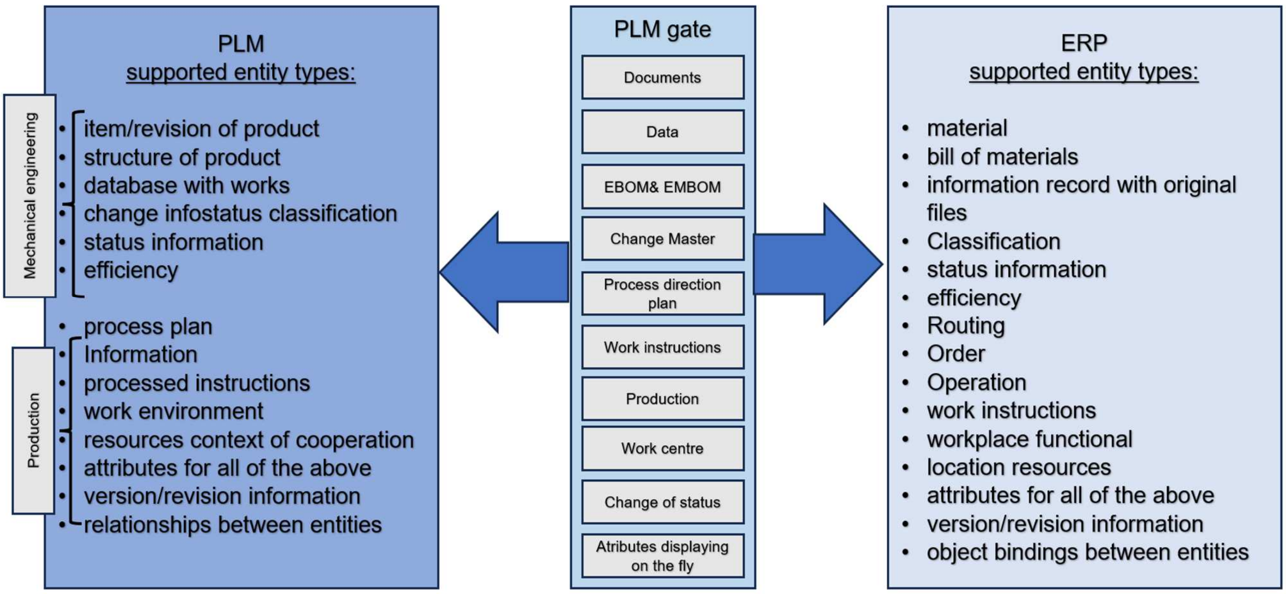

Figure 2 Interface between PLM and ERP data models

This integration must of course be parametric to be able to connect different data models of PLM and ERP databases and thus enable the sharing of monitored attributes, including the possibility of defining which system is the controlling system for which attribute and which only shares information. Among the key suppliers of PLM solutions that set the long-term direction and trend in PLM software development include:

- Siemens Industry Software - software PLM product Teamcenter.
- Dassault Systemes: software PLM product Enovia, software cPDM product SmarTeam.
- PTC- software PLM product Windchill.

All the solutions mentioned above are fully modular and cover the entire application portfolio of modern PLM.

2 Case study

Below are the outputs from the implemented case studies, which are related to the object-oriented approach in solving logistics. case studies were handled through the workplace of the authors of the article.

2.1 Dynamic production scheduling

Production Scheduling can be considered as a usually demanding discipline at the production level due to the possibility of different combinations even in the case of only a few products that the production produces. Scheduling can also be considered one of the most important processes for every manufacturing company. Schedules are usually presented in Gannt Charts. Scheduling processes have a short duration and must be rerun for each change. The average accuracy time of the schedule is very short, and therefore most authors report a continuous scheduling process in the literature. Scheduling is usually thought of as an iterative scheduling process that varies. Scheduling methods:

- Capacity planning (forward, backward, combined).
- According to the running time (to front, back, combined).
- Weighted planning (for example, for resources such as technologist, designer).
- Planning according to production bottlenecks.
- Operational planning common.

The APS/Advanced Planning and Scheduling solution itself communicates bilaterally between the ERP System and production. For each new schedule, he needs to get the status of new orders from the ERP system and the status of production equipment and work-in-progress directly from the factory. In most cases, this horizontal communication is enabled by the MES/Manufacturing Execution System solution, as described in Figure 3 [15-18].

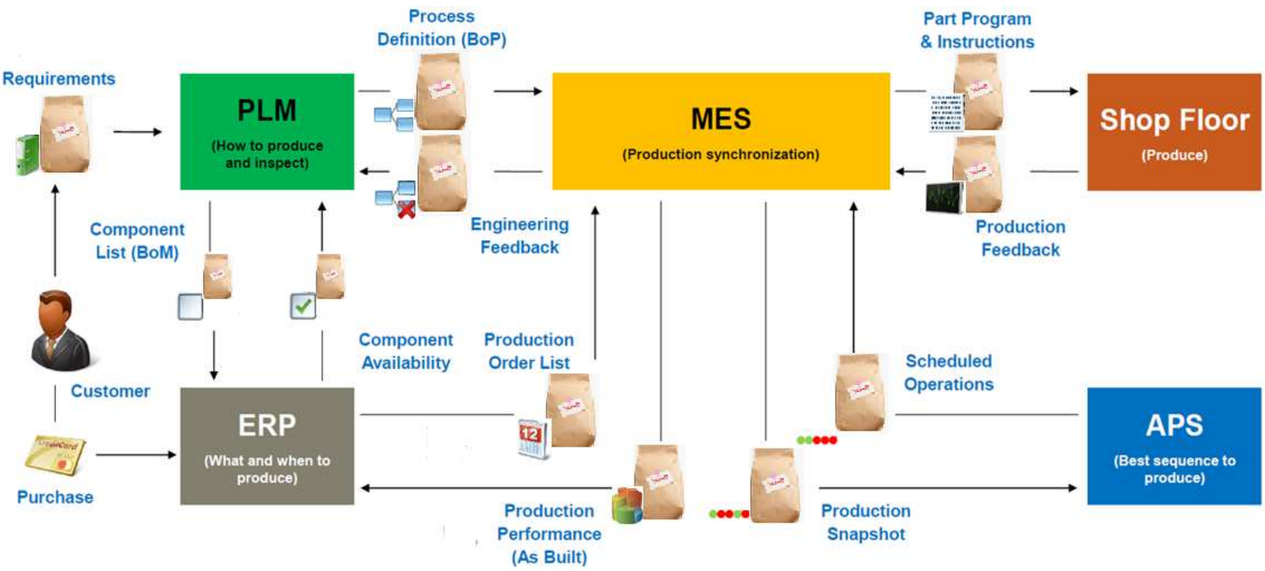

Figure 3 Interface MES + PLM + ERP + APS position [15-18]

Grouping work orders by material

Combining production orders according to the material that enters the production process can also be a method to optimize production and overall results. Consolidation of production orders improves the overall downtime caused by changing tools when changing from one type to another and also improves the results of failures. Figure 4 describes a Gantt chart in which production orders are connected. If we compare it with the first optimization method - forward scheduling, the difference is in the improvement of delayed orders and also the improvement of downtime when switching from one product to another.

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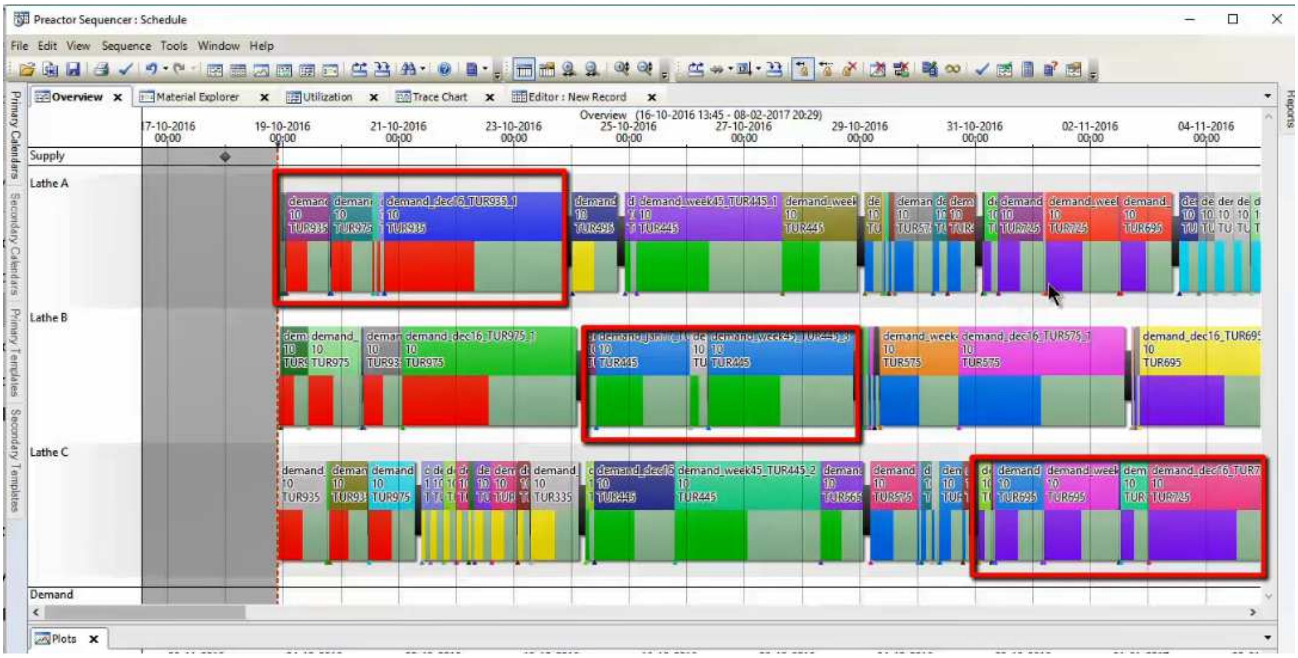

Figure 4 Optimization by combining work orders based on material - Opcenter APS Gantt Chart [15-18]

Forward scheduling is production in the forward direction from a defined starting point. The goal of such scheduling is to complete the process of each production order as soon as possible when the resource assigned to it is available with little or no waiting between individual processes. Planning logic: If the resource is available (the device itself, a specific role) the process is finished, but if the resource is not available at a given time, the process is waiting until the point when the resource is available again. Forward scheduling does not allow us to generate unfinished work orders but assigns them a delayed status.

2.2 Online Kanban implementation

With manual Kanban system the demand information is transferred through physical Kanban cards. Production launch signals are also sent manually from the customer to the supplier. However, this traditional Kanban system has its limits. Production continuity is endangered through incorrect manipulation with cards, either by their movement in incorrect time, or by their loss or duplication. As production times are constantly shortening and production volumes are constantly increasing, the amount of Kanban cards and, as a result, the amount of related problems with Kanban system maintenance and transparency is rising. Technical progress enables gradual replacement of the physical Kanban system through an electronic system, where signals are generated after demand and are automatically sent based on current needs. These signals are transmitted electronically. Every signal is recorded and kept which enables the comparison of historical data. The implementation of an electronic Kanban system may bring [3,6,10]:

- Kanban data management,
- increase of data rate,
- greater system transparency,
- support for the existing Kanban system,
- continuous improvement in the Kanban system.

The electronic Kanban system must follow the same principles as the traditional manual Kanban system. These principles include mainly the creation of a smooth flow of materials, synchronisation of production operations, elimination of bottlenecks and the establishment of a turn-based production system. The electronic Kanban system, similarly to the manual system, must continuously support improvement which is generally considered the most important sign of the Kanban system. The objective is to minimise stocks and production batches, which uncovers shortcomings in the production process and removes them after corrective measures are taken. The electronic Kanban system provides data collection, reporting on production operations and the flow of material and reserves and, in this way, contributes to the improvement as possible for data archiving. Working environment of the online Kanban system should be intuitive and easy to use properly. The electronic Kanban system should be user friendly as much as possible to meet possibilities of all users in the organization.

In comparison to the traditional approach, electronic Kanban system brings solutions in many areas, mainly [3,6,10]:

- elimination of card manipulations,
- elimination of problems related to a frequent loss of cards,
- better visibility of signals for the launch of production,

- improved communication with suppliers within the manufacturing process,
- analysis of supplier effectiveness within the manufacturing process,
- delivery of required material, ongoing production or ready-made products at the right time,
- minimisation of downtimes caused by the lack of material,
- improvement of supply chain transparency.

The electronic Kanban system solves many problems which occur when using physical Kanban cards. The process is more transparent, quicker and more reliable. It helps with solving problems associated with an error rate of production devices, manufactured production quality or the flow of materials and values within the manufacturing process. An indisputable advantage of the electronic Kanban system is the access to the system even outside the manufacturing process or even outside the manufacturing plant. Users and management staff can track and evaluate current data on the manufacturing process in real time.

The online Kanban system enables mediation of information on the status of every production station. The electronic Kanban system enables the implementation of the turn-based production system even in places where the traditional Kanban system often fails. Such places are production facilities with frequently changing customer demand. In such a case the electronic Kanban system within a computer application reacts to changes more flexibly and adapts the production accordingly. Electronic Kanban is currently also able to evaluate the impact of errors and failures on machines and equipment in the production process, thus minimizing the negative impact on the production plan.

The following Table 1 records main differences between the traditional Kanban system, which uses Kanban cards and Kanban boards for the transmission of information, and the electronic Kanban system, which runs as a programme in a personal computer.

Table 1 Comparison of the the traditional and the electrical Kanban system [3,6,10]

Traditional Kanban	**Electronic Kanban**
Useally chaotic data management – Acces, Excel or other general system	A specific system developed for Kanban
Difficult handing or large quantilies of Kanban cards	A large number of items are not a problem
Limited ability to send Kanban cards over lond distances	Automatic sending of data worldwide
Low order and stock transparency – not in real time	An up-to-date view fo orders and inventory in real time
Problematic definition of priorities	Priorities generated automatically
No record of historical data	Data is archived and evaluated using various tools
Manual transmission of data to the master system	Automatic data and report transfer

Contrary to the traditional manual Kanban system, the online Kanban system in many cases works using bar codes or RFID chips which mark materials, ongoing production and ready products. The RFID technology applies mainly internally within an organisation. Bar codes are suitable for the introduction of the Kanban system in the entire production chain, i.e. from material and component suppliers up to the final customer. These technologies also help record material movement in the production, either through bar-code scanning or through data collection by means of RFID readers. Data are displayed on an electronic Kanban dashboard. This board can be visualised on personal computers and various mobile devices such as tablets, mobile phones, etc. The tendency during last decades is to continuously increase flexibility and effectiveness of manufacturing processes. This trend also applies in the area of production planning and management. In view of the fundamental principle of the Kanban system, which is a continuous improvement, the establishment of the electronic Kanban system is a natural step.

2.3 RTLS technology use in TestBed

The practical example shown below was implemented in the specialized TestBed 4.0 laboratory, which is part of the KPaDI laboratories in cooperation with the SOVA Digital company, see Figure 5. To simulate the processes that can be implemented in the laboratory, a model was developed in the TX Plant Simulation software, which made it possible to test variant options during teaching.

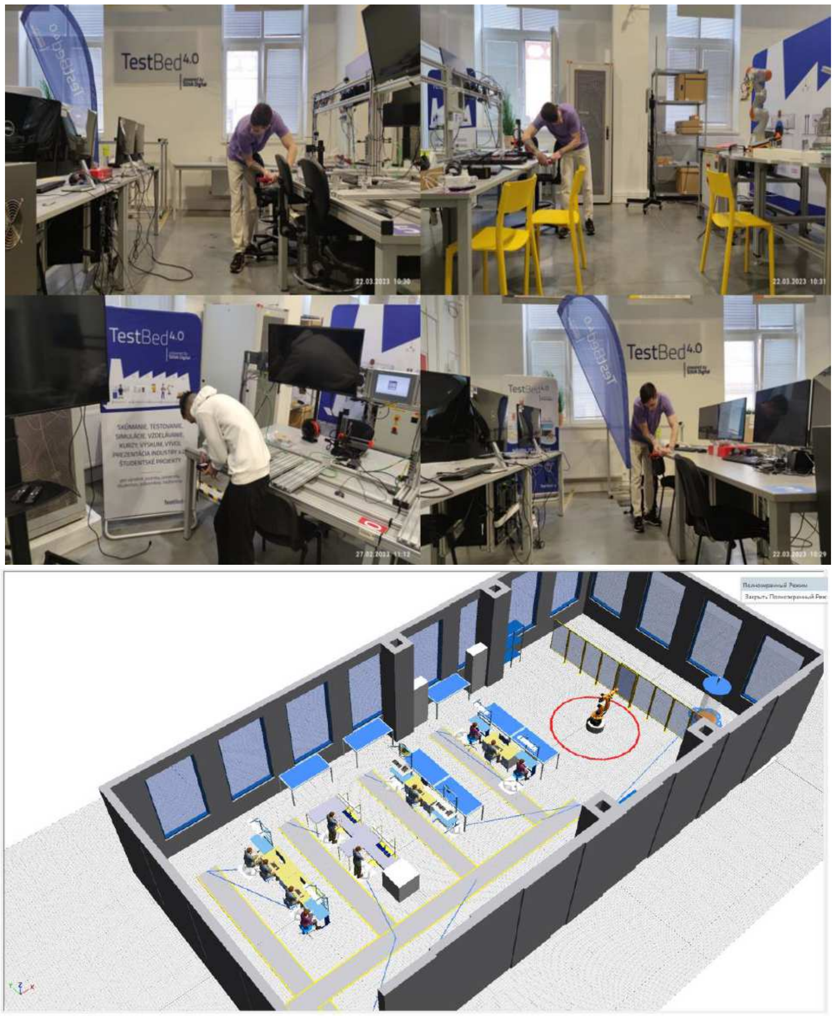

Figure 5 Project activity with RTLS technology in TestBed and 2D model in TX Plant Simulation

2D model was processed for tracking movement using RTLS/Real Time Location System software, Figure 5. By tracking the movement of the students through the tags they were wearing, it was possible to process the movements in the form of the above-mentioned graphic outputs. The collection of data on the movement of students around the floor plan of the laboratory was carried out, with the identification of activities within the laboratory and the identification of the most popular equipment of the workstations located in the laboratory from the student's point of view. With the help, it was possible to control and view the activity of students during their presence in the laboratory in real time. The outputs are shown in Figure 6.

The implementation of RTLS technology together with the simulation model and its 3D display will make it possible to create a more realistic and accurate model of the TestBed 4.0 training laboratory in order to further find new potential for increasing the efficiency of the educational process. Today's manufacturing companies and plants are subject to constant modernization, which is essential for success. The digitization of production data using industrial localization elements such as RTLS systems is increasingly recognized. This is due to the results of these systems in the area of workers' health protection, but mainly for saving production time, protecting property and products, and last but not least, for saving business finances. Managing business processes using information support means connecting and cooperating with people in a virtual environment with the aim of achieving the desired result in the highest possible quality [19]. The connection of PLM and ERP enables selected work processes (repetitive or based on a common algorithm of solutions) to be automated and thus speed up their course, to improve its quality by reducing the error rate and to make the processing of large volumes of data more efficient. Such a change in the way business processes are managed makes it possible to simplify the implementation of even the most complex processes, to ensure the correct distribution of tasks, the correct distribution of data to the right person and at the right time.

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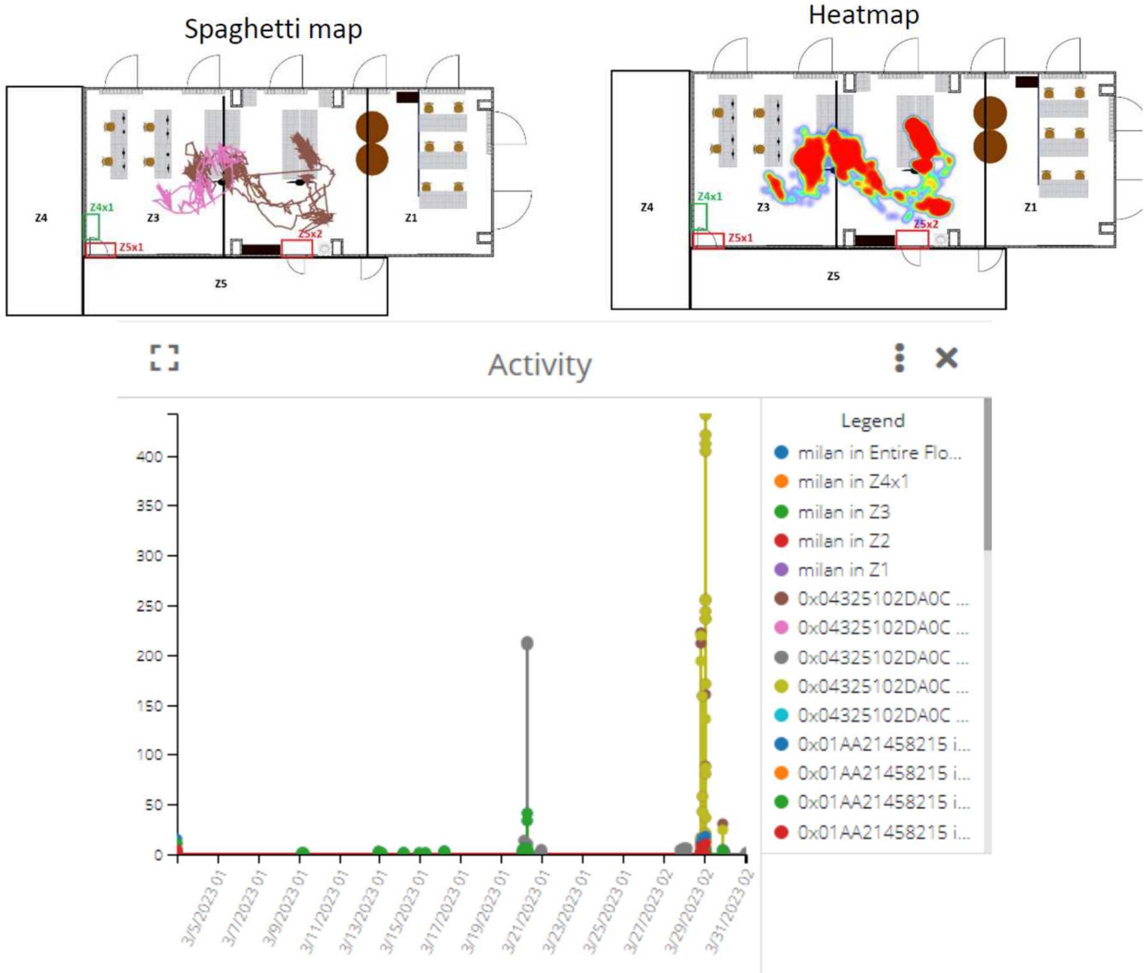

Figure 6 Previews the analysis from the RTLS software

The spaghetti diagram determines the continuity of the material flow for the possibilities of further optimization of processes and identification of inefficiencies in the organization of work, as well as wasteful transport and unjustified reduction of activity.

Heatmaps in general can provide a relatively high level of process clarity in that they can reveal the distribution and density of in-house operations as well as vulnerabilities that ultimately cause delays.

The activity can optimize the overall efficiency of use, e.g. fleet, employee, etc. Elements such as an inactive renewal and repair period are used. The data can be compared with each other.

3 Conclusions

Result of a logical sequence of steps that lead to the optimization of logistics processes through ERP collaboration with the business information system are processed in the algorithm presented in Figure 7. The goal of the created algorithm is:

- optimize the portfolio with a holistic view of information,
- effectively coordinate company resources,
- clearly understand impacts across projects,
- implement changes quickly, accurately, and comprehensively,
- maximize the visibility of work progress, resources, costs, and project status,
- simplify all types of processes in the company,
- digitize, optimize, and standardize production and non-production processes.

It is a sequence of steps, the aim of which is to effectively implement the customer's requirements into the desired output through the interactive cooperation of the concerned entities. In addition to a high-quality form of data analysis, it includes digitalization of models, simulation, evaluation of results, and standardization of processes. It enables interactive cooperation in the development of the proposal and the implementation of the selected proposal with entities that have access rights to the system anytime and anywhere, which is an indisputable advantage of this system, thereby increasing the quality and flexibility of work and reducing the costs associated with project implementation.

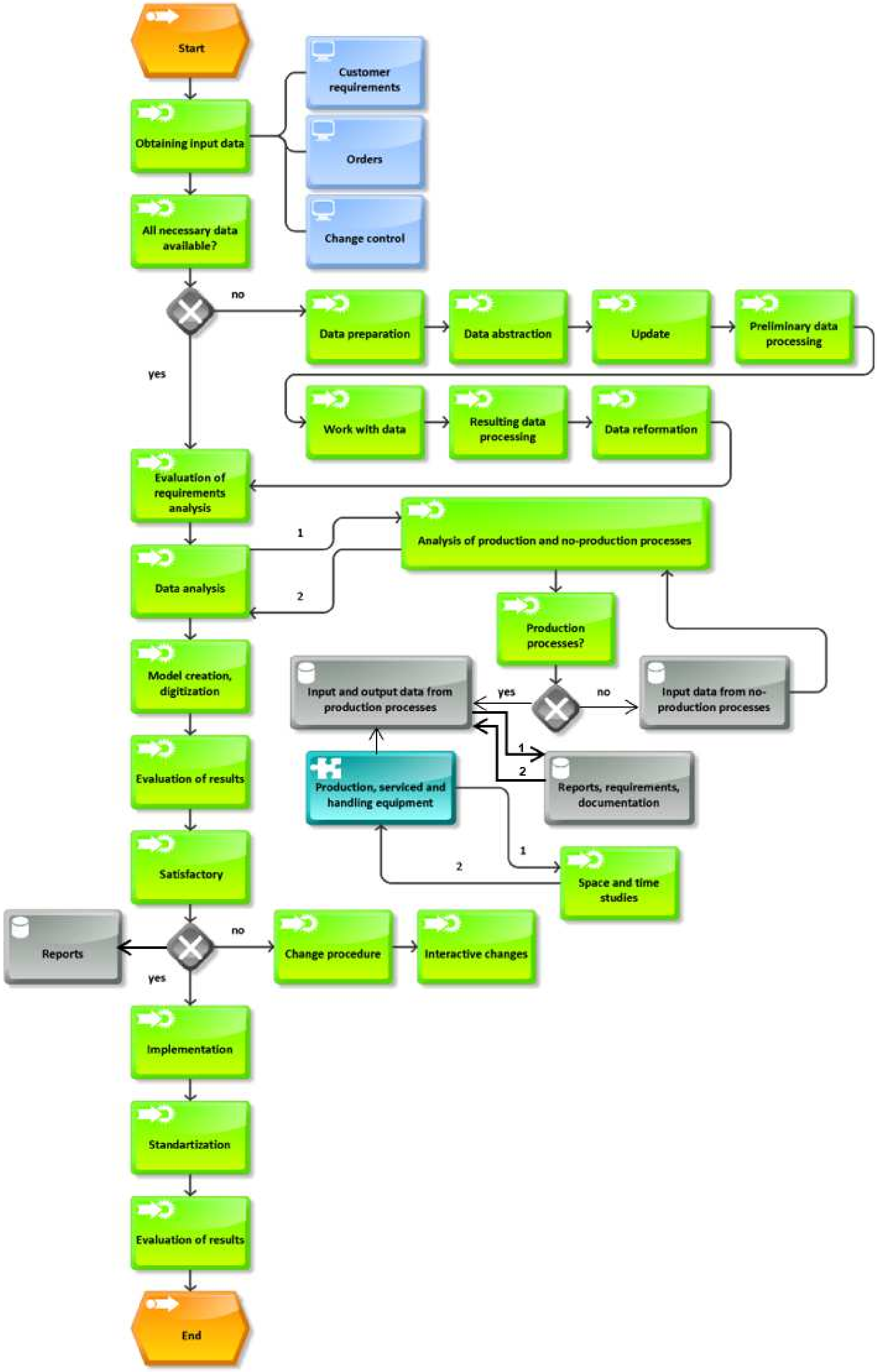

Figure 7 Algorithm for optimizing logistics processes through a business information system [used ARIS [20]]

The goal of the logistics information system is to achieve the interaction of physical processes with simulations in the digital model. This provides more detailed information into the functionality of production and logistics processes. The synergy between production practice and simulation technologies based on the principles of the digital twin enable complex analyzes of the cyber physical system, i.e. the physical device connected to its digital twin. The scope of these analyzes is not only the proposal of possible production situations and conditions, but also the backward applicability of the design output to the physical model. It is the area of analysis or the causality of change that brings about the development of areas of use of digital twins in the area of sophisticated algorithms for solving specific situations in production processes. The great benefit of the digital twin lies in solving complex logistical tasks and in the construction of e.g. electronic kanban, implementation of RTLS for real-time motion tracking, and other examples given in the article.

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