Optimization of Production Processes using BPMN and ArchiMate

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***Abstract*—This article aims to map and optimize production processes through the graphical form using syntax combination of BPMN and ArchiMate. In the first phase, the existing business processes of the manufacturing company in the Czech Republic were analyzed. In the second phase, the optimization of production processes was subsequently proposed. These optimizations were based on a combination of two ArchiMate and BPMN syntaxes with implementing ERP systems, enabling the design to utilize more efficient modern technology. The as-is-to-be process was documented in BPMN and ArchiMate, and a process-based simulation tool was used to quantify the effects of process improvement.**

***Keywords*—Production processes; graphic modelling; BPMN; ArchiMate**

I. Introduction

Today, ICT has become an integral part of any business. Companies that were able to use systems that helped automate processes had a significant advantage in the market and were ahead of the competition. That is why graphical notations have been created to reflect the critical areas of business architecture from the business and IT perspective. These methods can be used to identify the weaknesses of the company and propose the necessary measures to remedy them. Graphic business architecture is currently one of the essential tools that a company should address to improve its current market situation. [1], [2], [3], [4], [5], [6], [7], [8], [9], [10], [11]

Production is defined as an activity that a company carries out to provide products or services from which it obtains money from its customers. If production were focused solely on economic and social aspects, it would find itself in a situation where all production resources are used efficiently. Production efficiency is one of the most critical factors for the company's success. However, nowadays, when machines occupy a large part of the production, it is complicated to get ahead of the competition without buying new and more efficient machines. However, business processes can be better analyzed and identified. Thus, to improve the current situation not only in terms of production but also thanks to more excellent knowledge of production processes by individual workers.

Over the years, methods for proper production management have been gradually developed in industrialized countries, leading to increased efficiency. These methods are based on certain principles and philosophical approaches to production management that were implemented and recognized in their time. Their common feature is that they were created primarily to eliminate the inefficiency and waste of previously used methods in production control [12], [13], [14], [15]. Among the best known are:

- Material Requirement Planning (MRP)
- Manufacturing Resource Planning (MRP II)
- Enterprise Resource Planning (ERP)
- Optimized Production Technology (OPT)
- Just-in-time (JIT)
- Kanban
- Lean management

Graphic business architecture is currently one of the essential tools that a company should address to improve its current market situation. However, visual mapping also has its drawbacks, especially the time-consuming modelling and the low availability of aggregate materials from which to draw [16], [17], [18], [19], [20], [21], [22]. Many decision-making or simulation approaches can be used to support decision-making and process optimization. Among the best known are, for example, System Dynamics [23], [24], [25], [26], [27] or agent-based modelling [28], [29]. Often the company decides for reengineering after applying non-standard decision-making methods [30], [31], [32], [33].

This paper deals with the use of ArchiMate and BPMN languages for business architecture modelling. Each of these languages is a bit different, and each has an altered purpose, but both serve to map business architecture graphically. This work will combine both notations and utilize the necessary elements of ArchiMate language diagrams and the orientation on BPMN process modelling. A combination of modelling approaches is dealt with for example in publications [34], [35], [36], [37], [38].

The paper is divided into the following parts. The Background section briefly provides essential information on the approaches that are central to this paper. Section III. presents the current state, i.e. it describes partial diagrams belonging to the AS-IS model. Section IV. deals with the part of the model affected by the customer. The following, Section V shows the design of a TO-BE model for individual parts of the system. Section VI briefly summarizes the effectiveness of the proposed changes. In Section VII, we discuss the possibilities of using BPMN and ArchiMate in production companies, including a possible generalization of the presented approach. Finally, the Conclusion section summarizes the results and benefits of this study.

A. Industry 4.0

A separate and nowadays much-solved chapter of Production management is Industry 4.0, which is an advanced strategy of the German government aimed at automating the industry. It is based on cyber-physical systems (this system consists of physical entities that are controlled by computer algorithms, based on the cooperation of separate computing units that can make autonomous decisions) deployed to devices used in common areas of life. This primarily distinguishes industry 4.0 from ordinary automation of production systems and is therefore also called four industrial revolutions/ evolution. The basis is the Internet of Things (IoT), which is designed to enable the connection of a wide variety of internet-connected devices, which will open up new possibilities for controlling, monitoring, communicating and connecting home appliances, cars, but also medical devices. To deploy this system, all production facilities must include integrated communication standards through which CPS will communicate with those facilities. Industry 4.0 defines the concept of a digital factory into an intelligent factory that is adaptable, resource-efficient, ergonomic (human-friendly) and integrating customers and business partners into business processes. The arrival of IoT enables the transition from mass production to customer-oriented production. Production takes place in small batches and individual output, while there is no increase in the price of products. Automated machines and other smart tools used in industry 4.0 communicate wirelessly with IT systems that have a cloud solution. The combination of physical devices with their virtual data leads not only to improving production processes but also to changing the value chain from product design through production and logistics to recycling. For the introduction of Industry 4.0, it will be necessary to replace most of the existing business processes from product development to post-warranty service. However, the new intelligent factories with the help of IoT will not only be able to improve the quality and traceability of individual processes. Hence, products made precisely to different customer requirements, but will also enhance customer communication. Not only will it be able to monitor the condition of its product, but also the company can monitor predictive maintenance and thus optimize its production capacity.

II. Theoretical Background

A. Process Management

The process approach is based on the condition that the basic object of management is a described, clearly defined, structured, resource and input secured process that is created for a specific customer and having a clearly defined owner. The task of each process is to provide a product or service to one particular customer concerning its defined requirements, established rules and restrictions. The process requires some inputs and can use the resources assigned to it. A process is, therefore, a set of activities that interact and transform inputs into outputs.

Worth mentioning is also a functional approach to corporate governance, which is already outdated and ineffective. However, many companies are still using it abundantly today, and because of established practices do not even want to leave. The functional approach consists of a division of labour, in which the work is divided into the most straightforward tasks so that a certain number of specialists can perform even unskilled workers. This approach led to the introduction of mass production and the division of labour among functional units created based on their skills. This structure is also in line with the organizational structure, where the company is divided into divisions and individual departments, where each department only performs its tasks. However, it no longer follows the entire flow of business processes. In the case of this functional approach, each transition between processes, between departments, represents a risk point in terms of information barrier and time loss. The organization is then driven by the needs of each department and, to increase productivity as a whole, the productivity of each functional unit must be increased separately. Today, however, customers are very much involved in production and production is adjusted to their requirements. A functional approach is no longer practical and will not be sustainable for companies in the future.

In contrast to the functional approach, which places the main emphasis on the organizational division of skills, the process approach to management is oriented not only on the result of work (product) but also on the sequence of activities that lead to the achievement of the given product. Work is not performed in individual departments that are separated from each other, but work flows through these departments. Customer needs then drive the whole system. By using the process approach, the individual processes are gradually improved, thus optimizing them and simplifying the entire workflow. Both the title and the text imply that process management is based on business processes. To transition to this style of management is essential for a company to know its primary processes and be an expert in the field it is involved in because a company that does not know its processes cannot even want to improve those processes. On the other hand, when the main processes are known, it is possible to remove unnecessary processes and focus the company's forces on the main ones that will be further developed.

B. BPMN

Business Process Modeling and Notation (BPMN) is a graphical notation used to describe business processes. The primary goal of BPMN is to provide a notation that is easily understood by business departments and IT departments. The basis of BPMN is to create a description of a sequence of activities in a company, including events accompanying a process or communication between entities. BPMN was initially created by the non-profit Business Process Management Initiative (BPMI), which initially sought to set the standard for business processes as a means of developing e-business and B2B. To create graphical models, the Business Process Modeling Language (BPML), based on the XML syntax, was designed to define the same rules for all stakeholders. It has become a meta-language for business data modelling. This language was open, and everyone could download it from the BPMI website. However, since it was necessary to create a notation for this language that would be easy and understandable for everyone using this language, the BPMN notation was created. BPMN is, therefore, a standard for XML-based languages (e.g. BPML).

C. ArchiMate

ArchiMate is an open modelling language for graphical representation of business architecture, currently managed by The Open Group. The latest version 3.0.1, which was released in June 2016, is now in use and has been greatly enhanced and improved over the original version 2.1. The ArchiMate language is used to create a comprehensive view of the company but is not designed to develop too detailed models. Therefore, it is necessary to choose the right level of detail and thus, the appropriate language. However, none of the languages should go beyond their purpose and some degree of detail, as the description would become too detailed and could not fulfil its intended purpose. As mentioned earlier, ArchiMate can be linked to other languages [34], such as UML or BPMN, which can model selected areas in more detail. Both ArchiMate and BPMN use business processes for modelling, but the difference is in their application. ArchiMate models processes at the abstract level that are necessary for the design of enterprise architecture but are not designed for detailed process modelling. In contrast, BPMN is designed to model more detailed processes involving atomic tiles. ArchiMate is even closer to UML since most elements and constraints are based on UML. ArchiMate itself is not a methodology, but it is based on the TOGAF methodology, which includes methods and tools for creating, maintaining and managing business architecture. TOGAF emphasizes the creation of individual architectural steps aimed at constructing uniform models tailored to organizations. The structure of the ArchiMate language consists of 3 main parts (business layer, application layer and technology layers), which are complemented by motivational extension, implementation and migration extension completing the entire TOGAF framework [39].

III. Production: Graphical Modeling the As-Is Processes

A. Collecting Information

An exemplary example of the production of a standardized company was chosen to give a practical illustration of the above process. The company is engaged in the development of information systems for medium-sized companies. In addition to the creation of information systems, the offer also provides support services to customers, such as cloud computing, maintenance and possible complaints solutions or additional implementation of individual modules. Clients of the company are companies located primarily in the manufacturing industry. The customer can purchase the system itself and have it deployed to its servers, or it can only buy the system as a service and access the system remotely, and it will be stored on the developer's servers.

First, the models of the company providing the ERP system will be created and described and in the next step the customer models will be created so that the ERP system can be created according to these diagrams.

B. Organizational Structure of the Business Model

The ERP system builder, who is the supplier in this model, implements all the services that are depicted in the services provided to them. The services consist of the main services that are part of the purchased system, such as Maintenance, System Implementation, System Consulting and Training. Maintenance is a one-year service where the supplier provides free maintenance, performance improvement, or attribute modification. Under this service, we can see the system upgrade and help desk, which the customer can contact at any time. Another service is, of course, the implementation of the system, which is also related to the trial test operation. Consultations with the customer are processed during the systems development and training of all employees who will use the system. The rest of the services are additionally available and can be ordered at any time by the customer. All these services are provided to the customer through the offered ERP system. In this model shown in Fig. 1, the manufacturing company is in the customer's role. The case of using some of the services it makes payments to the supplier for these services.

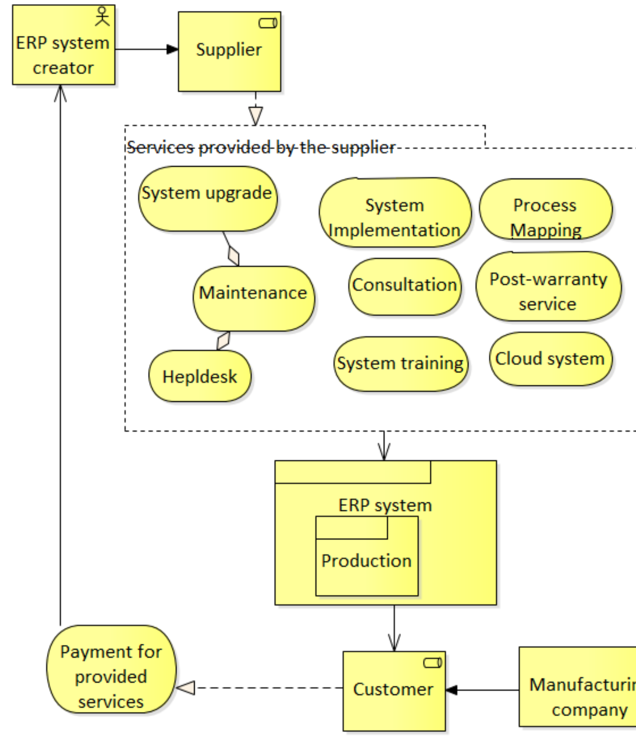

Fig. 1. Organizational Structure of the Business Model

C. Modelling of Business Processes of ERP System - Main Process

Because of describing only one ERP system module, the top-level model does not start, i.e. business processes, but shows the primary process of the production module. Also, this process does not create all the activities that can be carried out in the production department. However, it only models the system activities that are important for the development company and also for the presentation to the customer.

Fig. 2 describes the top view of the entire production process from system setup, through production planning to product handover. The figure shows that two types of events can initiate production. If the system configuration needs to be done first, the process is triggered by the first Production Implementation Start event. The system configuration activity

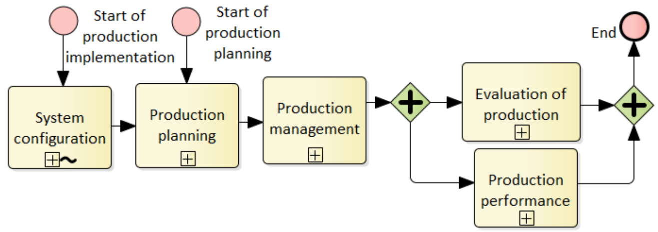

Fig. 2. The Main Production Module Process

itself is of the Ad-hoc type, that is, all nested activities can run in any order, but never two at the same time. After the system configuration is complete, the process flow continues to the Production Planning activity. This activity can also be initiated by the second event of the planned production start process. In this case, there is no system configuration, but the process starts right away in the second activity, where production is planned. After this activity, the flow continues to the Production Control, where the documentation containing the production operations themselves, the issue of material from the warehouse and the payroll slips are printed. In the next step, the flow is split and triggers both Production Performance and Production Evaluation activities simultaneously. The process can only be completed when both of these activities are completed.

1) System Configuration: A process is describing setting up the entire system so that the individual production orders are numbered according to specific rules. Determine the different products according to the specified parameters—the setting of specific tools, operations and all other components for proper system operation. Activities are nested in an Ad-hoc subprocess, so there are no links between them.

2) Production Planning: Process, see Fig. 3, describe the commencement of production operations. The process itself has two startup events. The first event, “Targeted Production Planning”, occurs when the production needs to be managed directly for a given customer. In this case, a production order is already created from the sales order that has already been created. In the second case, production is unaddressed, i.e. products that are intended to replenish stocks in stock will be produced. MRP calculation is then performed from both start events. After its preparation, the requirements for the production itself are processed. After processing the request, production is planned and ready for production.

3) MRP Calculation: This process, shown in Fig. 4, describes the Analysis of Production and Sales Orders and their subsequent processing. In the first process activity, these orders are processed in terms of inventory that is in stock. Find out if there is enough material or semi-finished product or already manufactured products in stock to cover the entire order. There may be several results at this point. First of all, there is a situation in which there is enough material in stock to produce. Therefore only the production requirement is created. In the latter case, there may be a situation where there is no more material available for production and must be secured through the sales department. That creates a purchase requirement to purchase the requested material. The third case is that only part of the production material is in stock. It is then necessary to

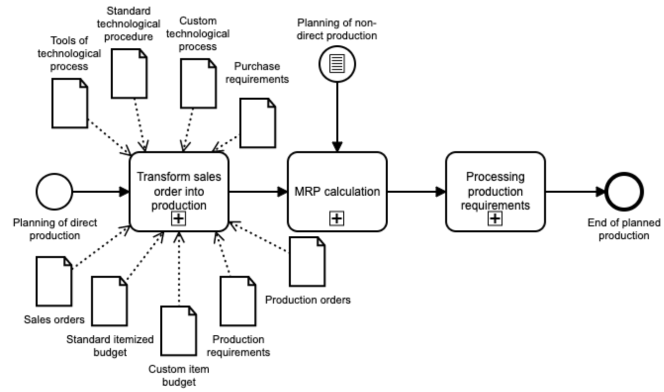

Fig. 3. Production Planning

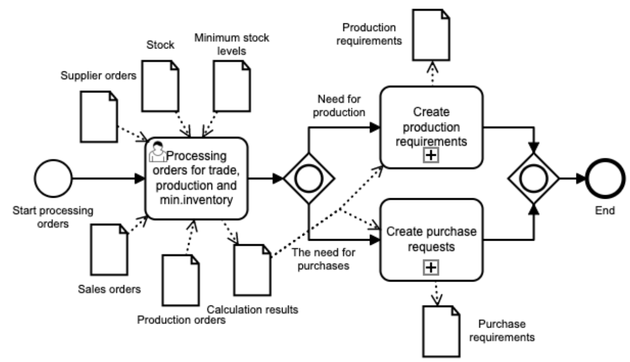

Fig. 4. MRP Calculation

create both production requirements to produce products from the remaining material and a purchase requirement to replenish the stock of required material.

4) Production request processing: The process illustrated in Fig. 5 describes the refinement of production requirements. One requirement can be precise from internal product parameters, drawings or customer wishes. After specifying the requirement, individual operations are generated, which must be performed to complete the product.

5) Production Management: The whole process begins with the event that the production order is included in production. After placing the order, the accompanying documentation is printed. This documentation contains the actual production operations, material delivery from the warehouse and payroll cards. The accompanying production documentation controls the individual production operations, the issue of the material is necessary for the dispensing of the required material from the warehouse, and the wage cards are referred to by the production workers, where they record the hours worked on the production of the given product. These documents may take various forms. If no other components are implemented, the process ends. If operational costing is still implemented, the Activity Costing Processing activity takes place. In another case, when the Operational Production Control is implemented, the so-called activity takes place. If the order analysis component is implemented, the so-called activity is implemented.

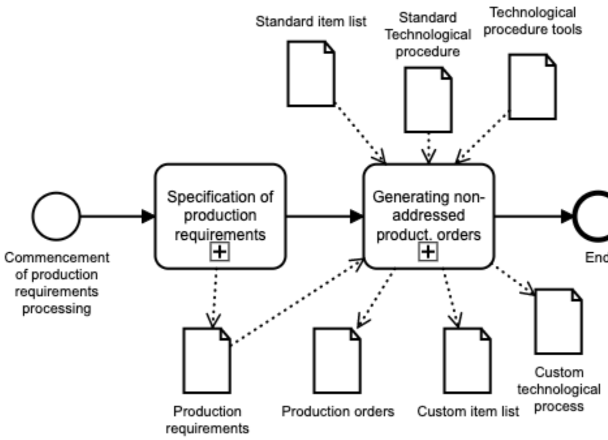

Fig. 5. Production Request Processing

The customer may have all or some of the additional functions implemented. At any step in this process, the Custom TPV Change Request event can be triggered. That is because the trigger is non-interrupting, and so triggering does not affect the operation of the second process. Depending on the situation, either the order or technological BOMs continue to be updated, or both can be updated.

6) Operational Production Control: Two events initiate this process; the first event is an automatic trigger after a given time interval. So it happens automatically. The second event is the manual start of the process and is determined by man. The first activity after these events is Move operations to the work stack, where the next process is determined. There may be other activities such as allocating the necessary material for the task and assigning work to individual workers, where the payroll sheets for allocation are printed. When the production resource allocation function is implemented for production, there is a capacity allocation before the work is allocated. Here the paths are divided whether the capacity allocation is done manually or automatically.

D. Production Performance

Two events initiate this process; one event is the processing of a given operation in production. The second event is to restart the next action. After these events, the Select Report Mode activity is performed, i.e. it is selected whether the operation will be initiated, interrupted, terminated or reported. These activities are either performed with or without allocation. After selecting and executing start, stop, or end activities, the reported asset will be processed, and if no asset is found for non-compliance, the process is complete. Either the process is repeated for another operation, or will not be repeated at the end of all production. If a report type activity is selected, a non-compliance check is performed.

If no mismatch is found, the process ends or is repeated. However, if an error is found, a report on non-conforming production shall be made. If a termination type activity is selected, a nonconformity check is performed, and if not found, the report assets are processed, and the flow continues as mentioned. However, if an error has been found, the documentation for non-conforming production shall be recorded. The documentation for reporting and non-compliance shall be processed. Then the process is either terminated again or is running over another operation.

1) Evaluation of Production: This process is simplified and put to the highest level, although it is apparent that all individual flows should be in separate sub-processes. The following activities are performed in this process: Production output is posted. The output is converted into wages, i.e. the work of individual employees is allocated to salaries, and the results of the whole calculation are processed. After all these activities have been completed, the evaluation of the production is over.

E. Application Layer

The application layer, shown in Fig. 6, provides a global view of the offered system and an overview of the modules and services that are offered. The diagram further describes that an ERP system consists of a module of production, trade, capacity planning, costing, shipping and sales that cannot be used without purchasing a module of sales. In case of interest, the customer can buy other systems such as CRM, Economy or HR module, which can be connected to the ERP system. The ERP system component thus shows all possible modules that the customer can buy and also what other systems and interconnections the company offers and enables. The production module is connected with services that these applications can be provided to the customer within the ERP system. The services that the system vendor depicts as application applications enter the customer's processes as business services that help execute business processes.

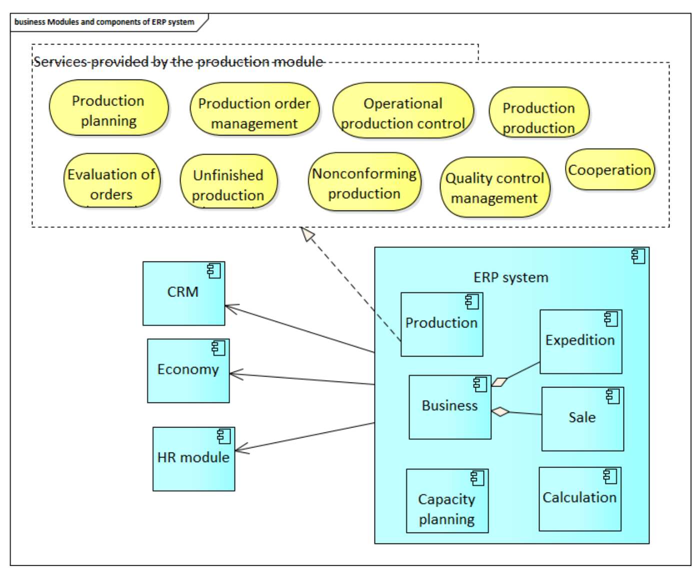

Fig. 6. Modules and Components of ERP System

IV. Modelling at the Customer

A. Defining Goals

When arriving at a customer, the most important thing is to find out what their goals are and why they want to replace the existing one or introduce a new system. These goals and requirements will help not only modellers but also the development company to identify what parts of the processes it is essential to focus on. The model captures the company's goals to be achieved after the implementation of the new ERP system. The strategic goal of the highest level deals with the improvement of the current situation in the company. To achieve this, the objectives at the lower level to which this objective is falling must be met. Enabling the reading of the QR code can be realized by the introduction of portable readers that allow the code to be read. Product improvement, according to customer requirements, can be realized by monitoring all unsuccessful offers. Customer feedback and subsequent analysis of the reasons for rejection will be collected for these offers. The goal of improving work efficiency is further broken down into two other sub-goals, which are Process Automation and Replacement of Existing Systems by One. Both of these goals can be implemented by deploying a new ERP system that allows automatic processing of some manual activities and also replaces existing systems with one system, resulting in greater system stability and increased ease of training for new staff. This principle The deployment of a new ERP system is crucial as it also positively influences (the plus sign of the binding) the introduction of portable QR readers and monitoring the reasons for rejection of the offer. On the principle of the new ERP system deployment, there are also three requirements, which are defined by the customer. In case of request modelling in BPMN, this model can serve as a basis for their creation. Looking at this diagram, shown in Fig. 7, some limitations could jeopardize the realization of the illustrated goals, such as sufficient HW to implement the system. However, if the customer does not have certain constraints along with the requirements, it is better to leave these rather speculative limitations to possible models, where the issue will be solved and not limit the model at all.

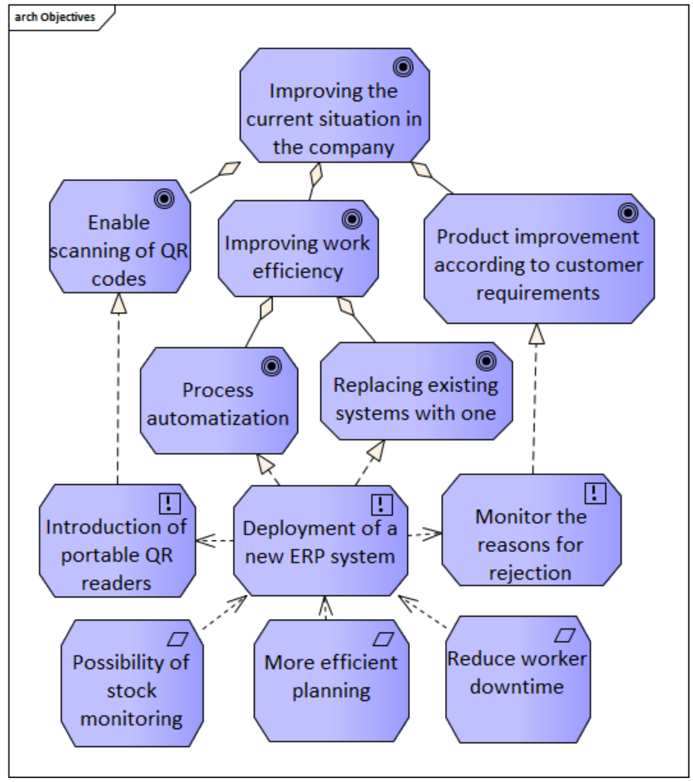

Fig. 7. Objectives

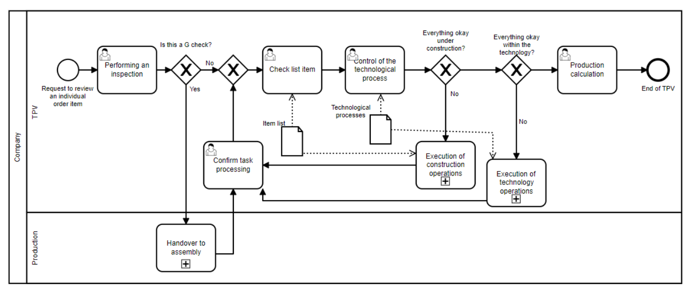

Fig. 8. Technological Preparation of Production

B. Technological Preparation of Production

Technological preparation of production (TPV) is not the production process itself. Still, it is closely connected with it, and as can be seen in Fig. 8, production processes appear here, and this part is most often part of the production module.

After the sale is complete, the TPV process is started, as shown in the business process diagram. When the sales contract is created and printed in the sale, the TPV process is started. First of all, the G check is carried out. It is a check whether a new product will be manufactured or whether a request for overhaul, modification or, for example, a product complaint has been received. In this case, the product is G, and it continues to be assembled to perform some of the above operations. If it is not a G product, the process proceeds to check the item list where the user in the system must check all subassemblies, parts and source material from which it will be produced. Next, the user performs the technological process check-in parallel with the item list check. Upon completion of both checks, the flow continues to condition that everything within the structure is OK. If not, the flow proceeds to the design where the design changes are made, which must be acknowledged, and the flow goes back to check the item list and process flow. This cycle is carried out until everything within the structure is in order. It must then be ascertained if all is well within the technology, and the process is proceeding in a similar way to the construction condition. After a successful technological check, a calculation is made, and the TPV process is terminated.

C. Backbone Production Process

If the business process breaks down into multiple levels and not just one, as was the case with the TPV process, it is advisable to create a second level from a subprocess that will contain the process itself, and the knife will also drop to even lower levels. This diagram, shown in Fig. 9, is elementary: first, the production will be started, then the assembly and the final product will be dispatched. However, there are events between the sub-processes that contain the condition, and without meeting the condition, the flow cannot continue to the next process. Taking into account, for example, the conditional event between production and assembly, it is clear that assembly cannot begin until all the necessary parts are available to the final product composition.

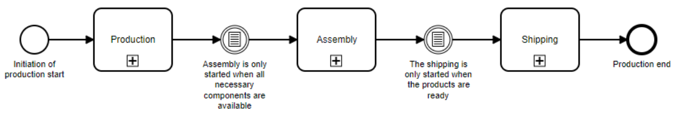

Fig. 9. Backbone Production Process

D. Production

The production process, shown in Fig. 10, begins with its planning. As mentioned above, this process will further disintegrate and will be described below, as its complexity could lead to a large diagram and its confusion. The next step in the process is to assign work to specific workers. In this activity, work will be progressively allocated to each worker until all the work is divided. The worker takes his assigned work and goes to do it. After the product has been produced, the work must be physically submitted. After submitting it, the worker must go to the computer and specify that the work is complete. In the system, in the Job Assignment section, the employee appears with a marker available to enter a new job, indicating that the current job is already done. At the moment, but the product is not finished yet. It must first undergo quality control before being labelled as a finished product. The manufacturing worker does not have to wait for this fact and can already produce another product. The next step is to pass the cover sheet back to the planning, and if it was not the last operation of the product, the work is assigned to the worker. In the case of the previous operation in the accompanying document, the product will be stored and registered. However, it must first be decided whether it is the final product and will go to the finished product warehouse or a semi-finished product that will go to another warehouse.

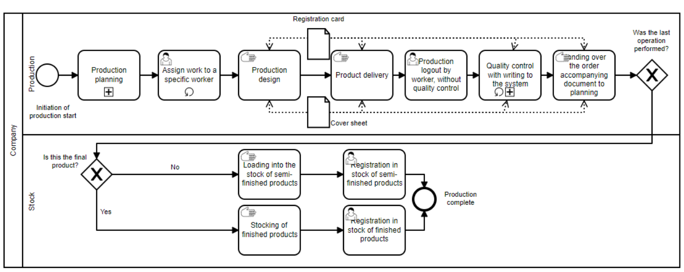

Fig. 10. Production

E. Production Planning

This process takes place at the very beginning of the production process. Thus, before all the activities described in the previous diagram. For a general view of production, however, this detailed planning process is not needed, and therefore, it is put down to a lower level and described at this point. The user finds a specific order in the system, for which he has to find the parts from which the product will be composed. They must create a production plan for these parts and print the accompanying documentation. In this step, it is worth noting the trigger of the message type (Receiving a new production order). This event will be referenced in the following quality control process. After the accompanying documentation has been printed, it must be decided whether it is a finished product - then the product labels are printed. In the case of the production of semi-finished products, the flow continues on the condition, whether it is a W order. Production orders are divided according to the number of pieces produced, if there are 20 or more pieces, the production order is marked with the letter W and registration plates must be printed. In another case, it proceeds straight to the work stack, from which it continues to be used for assigning tasks to individual workers.

F. Quality Control with Writing to the System

In production, it is possible to see a sub-process of checking that is performed for each product separately. The process, shown in Fig. 11, is started when the employee submits the product as finished. The inspector conducts a quality check. If the check is OK, logs off the product in the system with the check performed. That completes the inspection process and can resume production. If the product has not been inspected according to the product requirements, it must be entered into the inspection report system, and a committee is called to assess the next steps of the product. If the product cannot be repaired, two manual activities are performed in parallel: Transfer the product to the scrap store, where this inspection thread is terminated, and the second activity Urgency evaluation of the product. Here it is decided whether the non-compliant product must be re-manufactured or can be dispensed with. This decision can be made because the so-called economic benefits plan some products. That means that when a user intends to manufacture, he will enter the number of products that will be most advantageous to manufacture, taking into account the cost of manufacturing and storing unused products. Thanks to this, there can be a requirement, e.g. ten products, of which two are bad, but only one is required to order, and therefore it is not necessary to produce another product again, and this fibre is terminated.

In the second case, the user creates a new production order, and it is sent. Here we can notice the end event of the message type. In this step, it is useful to remember the production planning and trigger event of the same kind. This event is triggered only by the Send Documentation Report from the Quality Control event. The arrival of that report restarts production planning, but not at the beginning of the process. It restarts from the Print Documentation Activity that triggers the receipt of the report.

If the product can be repaired, the need for a change in TPV will be reviewed. Assuming that a TPV modification request is entered, the technological process is manually modified and submitted to planning. The process thread ends by sending a product repair start message back to production planning. This part is similar to the creation of a new order. With the difference that the process does not start with the printing of the accompanying documentation, but the modified technological procedure is inserted directly into the work tank.

G. Construction

Fig. 12 shows the assembly process. The assembly of the product begins after all the parts needed to assemble the final product are in stock. The process initiates the users entering the

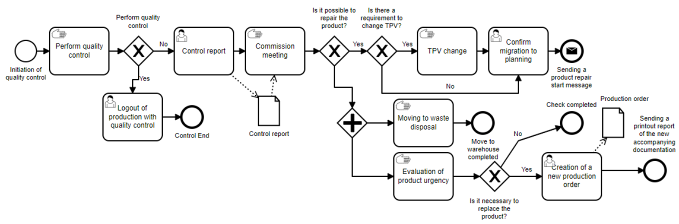

Fig. 11. Quality Control with Writing to the System

information about the material, which needs to be picked for the given product. Entered products are picked and delivered for assembly, where the product is finalized to the required state. The assembled product is submitted for quality control, and all operations performed on the product are entered into the system. In the next step, a quality check is carried out to determine whether the product complies with the requirements, as in the production part. If the product is not correct, it is returned to the assembly. For a product that has been inspected, it is assessed whether it is necessary to paint it as required. If so, it is painted and stored. If there is no need to paint the product, it is transported directly to the finished product warehouse and registered in the complete product system.

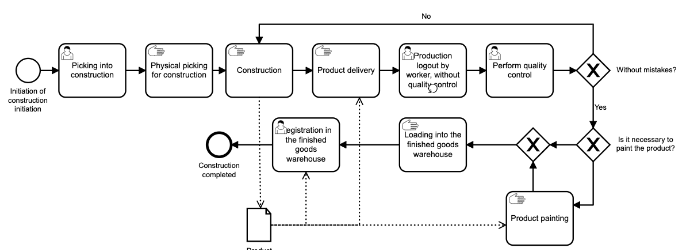

Fig. 12. Construction

H. The Current State of the Technological Part of the Company

Fig. 13 describes the current state of the technological infrastructure of the company so that it is clear where the new system will intervene and what system or hardware will use this new system. The diagram shows that the buildings of the manufacturing company are located at three different locations and communication is carried out via the Internet. That means that the system will also need to be secured for communication outside the intranet. The headquarters of the company contains a database and application server, which together with workstations and production machines are connected via a local network. The company headquarters communicates with the warehouses via the Internet, except for the semi-finished warehouse located directly in the headquarters. In the second location, called the Butcher Shop, there is only a workstation with a barcode reader and a firewall that accesses the servers via the Internet. Furthermore, there is a cutting machine that only represents the purpose of the location, but is not connected to the system. In the third location, External Workstation, the workstation is located just like in all other locations. Besides, there is a simple automatic stacker that loads goods based on barcodes.

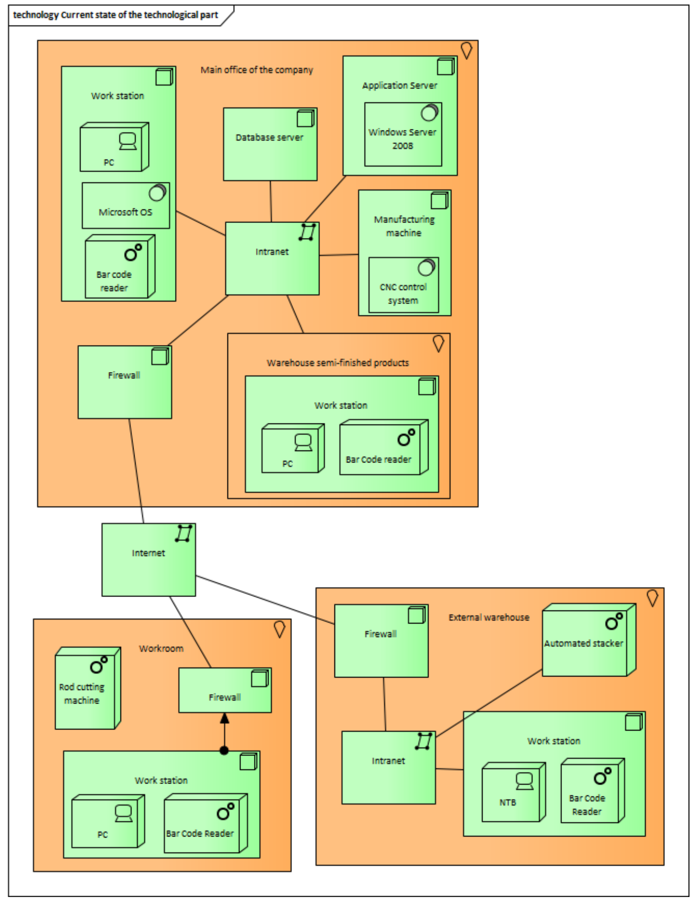

Fig. 13. Current State of the Technological Part

V. Results: Process Analysis and Development of the To-Be Process

A. Process Evaluation

After creating the as-is model, the process was evaluated with a focus on weaknesses and potential for improvement. The evaluation is based on two quality criteria, efficiency and effectiveness. Harrington [40] defined the process efficiency as "the extent to which the outputs of a process or sub-process meet the needs and expectations of its customers". The effectiveness of the process then refers to "the extent to which resources are minimized, and wastage is eliminated when seeking efficiency". In our case, we evaluated process efficiency as fulfilling the necessary process functions, while process efficiency was assessed by identifying the bottleneck of the process.

B. Target State of the Technological Part of the Company

The general processes of the ERP system and the processes of the manufacturing company itself differ considerably. However, it is possible to start a large part of the activities and use these activities in the implementation of the new system. When designing a solution, there must be no transformation and effort to adjust the activities of the manufacturing company so that it is as simple as possible to deploy the system. Still, the system itself has to be modified. System creation is usually customer-oriented. That means that the current system is being modified according to the client's requirements to achieve the highest possible satisfaction. In the following years, he turned to the relevant supplier again. However, the customer is satisfied when if the system works well, and the workers do good work. Moreover, since most people are poorly accepting changes and taking every new thing as unnecessary, human processes must not change to a large extent, but, above all, there is a change in the processes that the computer is doing. The target state of business processes and technological part is realized by projecting changes into the models of the current state of the company.

C. Impacts on Technological Preparation of Production

Like the business process model, the TPV process, shown in Fig. 14 is based on the current state of the company and tries to maintain the same processes that they already have in the company. Nevertheless, many changes have been made to this process, especially the automation of some activities. Before the process starts, it can be known whether the activity G is not performed by the employee, or is replaced by the system. It decides whether it is a G order and, if not, the flow continues to three parallel activities for which two employees are no longer needed, but the system executes them on its own. Here, too, there was one activity, which is Control for the actual product. In this activity, the system checks whether the order contains all the necessary requisites, such as the filled-in product name, whether the goods group is correctly entered or whether the item number is filled in. The flow continues in the usual way through several conditions until a new condition is established to determine if MRP calculation has already been performed. In case the calculation has not yet been calculated for a given order, two new activities are launched simultaneously. MRP calculation itself and checking the last cost calculation for the final product. If the calculation for the product exists and is less than half a year, the TPV process is terminated. Otherwise, we have to make a new calculation, confirm it, and the process goes back to the checks.

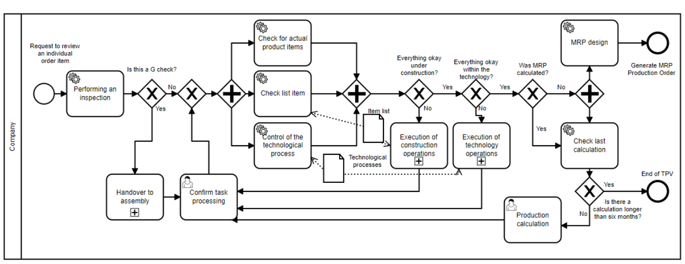

Fig. 14. TPV

D. MRP Calculation

As already mentioned, this process is new, but its considerable similarity can be seen in the production planning process except that the system only performs the whole process. The process is started by generating a production order from the TPV process and starts processing the individual lines of the business order. Then, a Disintegration Check is performed to detect items disintegration. These create an overview of which materials and blanks the part is produced from. Find out if it is a purchased item, or the product is already in stock. In this case, the MRP calculation would be terminated. Otherwise, a production order is created, and the accompanying documentation is printed. In this production planning process, the patron was notified of a message trigger event. That is replaced by a signal event that is triggered by another part of the system. After printing the accompanying documentation, the production order is entered in the order sheet. After this step, under the same condition, it is decided whether to print the product labels that the system generates and prints. Registration labels are already replaced by QR codes and are always printed for each job. The MRP calculation process, shown in Fig. 15, ends when the order is generated to the work stack.

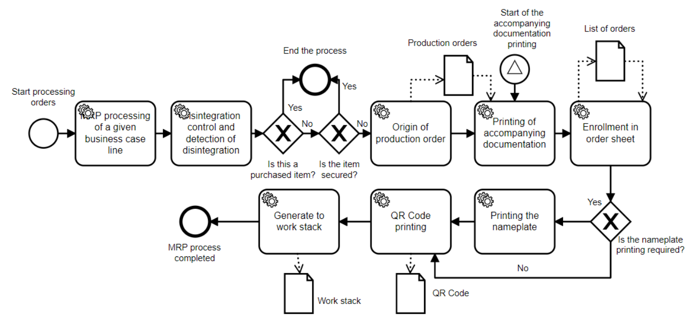

Fig. 15. MRP Calculation

E. Target State of the Backbone Production Process

There were two changes in the backbone process in Fig. 16. First of all, it is possible to notice a timer trigger. The production process is automatically started 20 minutes after midnight. Also, there is the Workshop Planning activity, in which the system schedules production times for each order, as well as the approximate number of orders that should be produced per working day. That means that planning staff does not have to plan the entire production, but only assigns tasks.

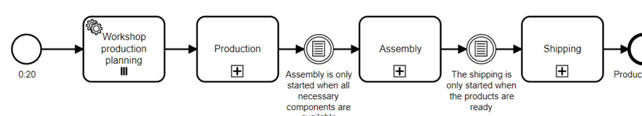

Fig. 16. Target State of the Backbone Production Process

F. Production

Production, Fig. 17, begins with acceptance of the accompanying document for production. Here, only workers assign work to individual workers, and they can start working. Until now, this activity could not be entirely replaced by the system because the human factor and knowledge of workers are continuously required when assigning work (e.g. worker A may produce three products in the same time as worker B only 2). Another significant change is the handing over of the finished product. The worker will no longer have to go physically to hand over the product and then unsubscribe in the system, but this step can be performed simultaneously. That will be possible with the use of portable QR readers located directly at the product delivery point. The worker will retrieve the location where the product will be placed, as well as the product code. That will lead to simplification of work, but also ensure that no other component than the final product is to be used during assembly.

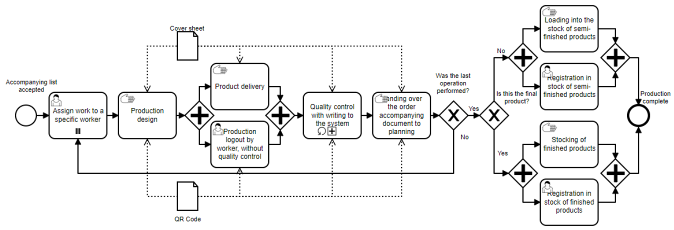

Fig. 17. Target Production Model

G. Target State of Quality Control

As it is possible to see in Fig. 18, there were no significant changes in quality control as in other processes. The changes mainly relate to non-repairable products, the so-called scrap: their transfer to the scrap store is newly recorded in the system. Due to using a QR reader is possible to perform these activities together, as well as when handing in other products. Another change occurs when evaluating whether it is necessary to manufacture the defective product again. The worker will no longer create this task, but the decision will be made automatically by the system. It is up to the worker to develop a new production order. There were also two end events: from message to signal. That is because workers no longer carry out production planning, but the system performs this process. Thus, the user only needs to create a new order or production plan, and the system automatically moves it to the MRP process.

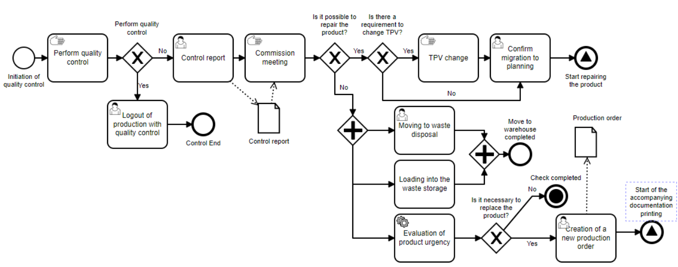

Fig. 18. Target State of Quality Control

H. Target Construction Status

The construction to-be model shown in Fig. 19 only simplified the picking and delivery of products by introducing QR codes. The rest of the construction process remains unchanged.

I. Target State of the Technological Part of the Company

To implement the ERP system is necessary to replace the existing application server with a new, more powerful, as it is possible to see in Fig. 20. The ERP system will be performed on this server, which will be accessed by both existing computer stations and newly acquired QR readers. Another change is the QR readers mentioned above, which will replace old computer stations used only for barcode reading.

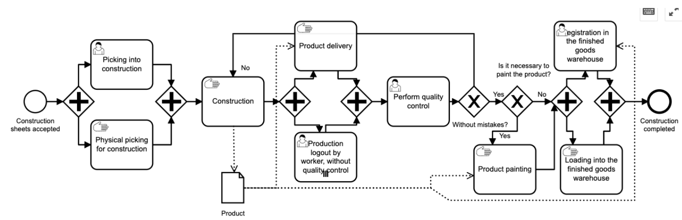

Fig. 19. Target Construction Model

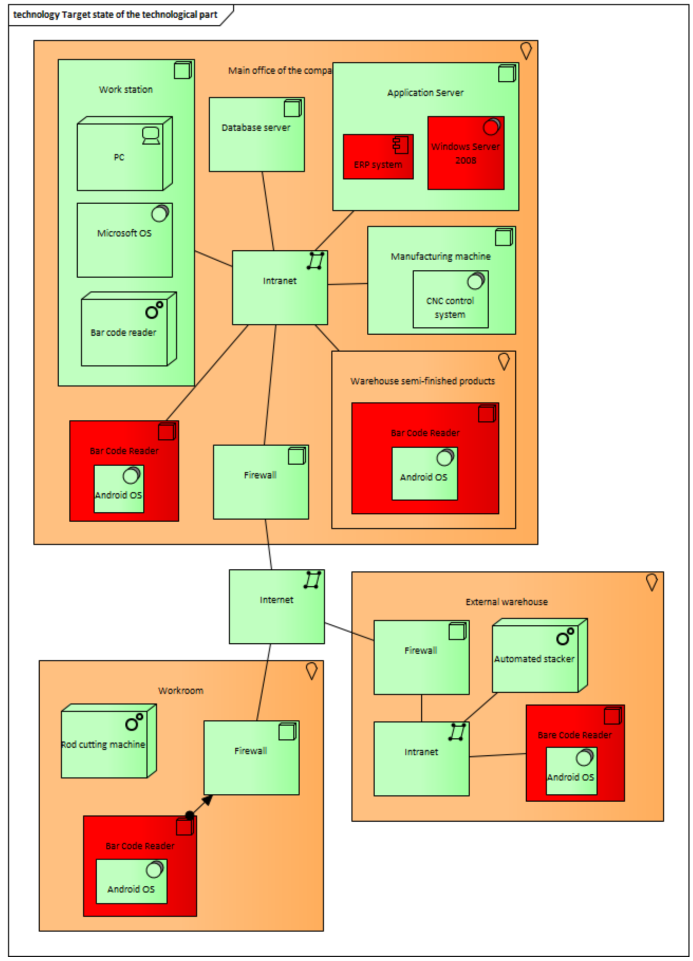

Fig. 20. Target State of the Technological Part

VI. Quantifying the Impact

The primary function of the as-is and to-be process models in the improvement project was to facilitate communication between key stakeholders. The process layout was designed as simple as possible to minimize the technical impact of the modelling tools used. After analyzing the production process, the weaknesses and improvement potential was understood. The company requested to illustrate the potential financial impact of the new process design using a simulation approach. For this purpose, the existing process maps needed to be extended. All data on time required for individual activities as are necessary for financial analysis were obtained from the company. An expert estimate estimated the system load of the proposed new activities and service bags.

The simulation showed significant differences in cycle time between as-is and to-be scenarios. Since the time saved by the design of the to-be process has brought additional process capacity, the economic return on carrying out the future process is mainly in the potential increase in profitability due to additional capacity.

VII. Discussion

The mapping of enterprise architecture is possible also by the use of other ArchiMate diagrams. E.g., an organizational structure diagram or diagram of enterprise standards. However, especially network and data infrastructures diagrams can currently be used to analyze data security within the GDPR (General Data Protection Regulation). Processes modelled with BPMN could be enhanced with business process simulations that can show how they can be optimized to make them as efficient as possible for the business. The languages introduced in the thesis can be further enriched by UML, which would add complexity to the whole modelling and thus enable to capture more levels of enterprise architecture.

The generalizability of the presented model and approach can be discussed in terms of methods and focus. In Article [41], the authors stated that ArchiMate and The Value Management Platform (VMP) could be connected. They also proved that ArchiMate value streams, capabilities and resources are all strategy layer elements in the enterprise architecture, reflecting a level of abstraction in modelling common to VMP. In Article [42], the authors examined the limitations of the ArchiMate and SOMF languages. The paper [43] elaborates an adaptation of the profile mechanism from UML for generic extensions of meta models in the field of enterprise modelling.

VIII. Conclusions

The interconnection of the ERP system together with QR code readers, will bring a positive effect not only for the manufacturing company but also for employees, who will be relieved of some of their work. The management will be able to monitor the progress of various operations and the movement of materials and products, thus avoiding the use of defective parts and improving the company's visibility. With the help of estimates and predictions, planning of both short-term and long-term goals will be much easier. With the help of process automation, the company can use the full potential of workers who have been delayed by demanding activities and could not fully devote themselves to their work. That will also help the night running of the system. However, setting up new processes related to the implementation of a new system and changing the technological infrastructure may also entail certain risks that a company must consider before deploying the system.

Acknowledgment

This work was supported by a GACR 18-01246S and the Faculty of Informatics and Management UHK Specific Research Project. The author would like to thank T.Lepš for his cooperation on this topic.

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