Project of Rationalization: Production Process Scheduling in Kovárna VIVA a.s.

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Zásady pro vypracování:

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Definujte cíle práce a použité metody zpracování práce.

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- **Zpracujte literární rešerši vztahující se k dané problematice.**

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- **Zhodnoťte stávající způsob plánování výroby.**
- **Zformulujte požadavky na modifikovaný plánovací systém.**
- **Navrhněte databázi vstupních a výstupních dat pro plánovací algoritmus.**
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Závěr

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L.S.

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ABSTRAKT

Práce představuje přípravnou studii pro optimalizaci plánování a rozvrhování výroby ve společnosti Kovárna VIVA a.s. Hlavním cílem práce bylo odstranit zjištěné nedostatky současného způsobu plánování. Dílčími cíly bylo formulovat požadavky na modifikovaný plánovací system a poté návrh a implementace databáze. Naplnění uvedených dílčích cílů umožnilo navrhnout algoritmus, který spolu s databází může sloužit jako podklad pro samotnou realizaci projektu v dané firmě, a přesto je toto řešení v mnohých aspektech použitelné pro řadu podobných typů výrob. Projekt vychází z analýzy současného stavu a přihlíží k vlastnostem použitého podnikového informačního systému a následně pomocí vývojových diagramů formalizuje jednotlivé činnosti v procesu plánování a rozvrhování výroby. Výstupy těchto činností byly předloženy ve tvaru, který má sloužit jako podklad pro obecné zadání implementace záměru externím dodavatelem daného podnikového informačního systému.

Klíčová slova: plánování výroby, podnikový informační systém, relační databáze, výrobní dávka, srovnávání alternative, omezující podmínky

ABSTRACT

The master thesis constitutes a preliminary study for planning and scheduling process optimization in Kovárna VIVA a.s. The principle objective is to formulate the requirements for the planning system in order to design relational database and its further implementation. Achieving the particular objectives enabled to design an algorithm that, together with the database, serves as a basis for the actual project realization. The proposed solution is meant for Kovárna VIVA a.s. primary, however due to many aspects it is utilizable to a variety of similar types of production. The project is based on an analysis of the current situation in accordance to properties of the corporate information system. Therefore, the particular planning and scheduling steps are described by several flowcharts. The outputs were submitted in a form suitable for further implementation provided by the external vendor of the corporate information system.

Keywords: production planning and scheduling, corporate information system, relational database, production batch, alternative comparison, constraint conditions

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"As the complexity of a system increases, the ability to make precise and yet significant statements about its behavior diminishes until a threshold is reached beyond which precision and relevance become almost mutually exclusive characteristics."

Lofti A. Zadeh

CONTENTS

INTRODUCTION

Each enterprise during its existence aims to improve the efficiency of its activities, this effort is reflected in a wide range of managerial sub-activities. Industrial Engineering mostly deals with reducing costs and increasing the efficiency of internal processes including their organization concerning a technological aspect as well.

For the successful performance of managerial activities, it is necessary to ensure sufficient amount of relevant information. Furthermore, it is necessary to specify the fields of activities for individual managerial position including competences delimitation.

In terms of increasing the efficiency of internal processes, the ERP systems are deployed, this fact enables to store, share and utilize corporate data in order to speed up the internal processes, inter alia, the usage of ERP is fundamental for an effective production planning and scheduling processes.

Many manufacturing enterprises are facing the need for valid and well-timed data entering the corporate information systems. The information system providing this functionality commonly arises from a set of distinguished subsystems. Such a decentralized arrangement of data processing brings additional secondary problems of data conversion and transformation making the communication among the information systems components possible.

The major problem in the field of production planning and scheduling process is the unsufficient information utilization in particular steps of planning activities, especially in customer order processing. Another serious shortcoming is the low level of automatic information issuing and sharing. The data enters the ERP after face-to-face communication insted of their generating on the spot of their appearance. In order to eliminate the negative impact of mentioned problems, the optimal solution was sought to redefine the process accomplished within the specific roles of individual ERP users.

The aim of this project is to rationalize the process of production planning and scheduling. The thesis focusses on a solution ranging from the customer order processing up to production reporting in Kovárna VIVA a.s. The purpose of the project is to create a conceptual model encompassing both information flow optimization and database design required for the application of the proposed planning method.

This conceptual frame aspires to be applicable for similar types of productions in the manufacturing industry.

OBJECTIVES AND METHODS OF MASTER THESIS PROCESSING

The past experience with the ERP system utilization in the field of production planning and scheduling initiated the need of the process streamline. This need for rationalization resulted in the thesis assignment.

The current trend in business process management is the deployment of ERP systems. In general, the first step is to choose the suitable ERP, the second step is the ERP implementation itself with appropriate level of customization provided by the external vendor of the ERP mostly in cooperation with the company management. The aim of the master thesis is to provide all the relevant information in order to expand and further improve the production planning functionality in the ERP.

The project is intended for Kovárna VIVA a.s. currently using the ERP system abas. The project proposal is designed specifically for that company, however it contains some principles whose applicability goes beyond the application and can be useful for a number of SMEs.

Considering the complexity of this issue, the final decision have not been made yet. The management of the company should decide to what extent the project is meant to be implemented concerning the timeframe of the implementation. In this case, the master thesis serves more as a preparatory study for further decision making of the company management.

The project is based on current planning and scheduling process analysis that results in finding of several fundamental shortcomings in various stages of the planning and scheduling process. These deficiencies are essential for the improvement proposal. Some of the planning process have been redefined, the roles of individual participant in the planning process were modified. The interactions between the ERP and particular ERP users were described using the flow diagrams and moreover, the requirements for the ERP functionality were formally described through the design of the relational database, which now includes many important properties of the planning process entities. The proposal left some space for further discussion and improvement of proposed solution.

I. THEORY

1 MANUFACTURING PLANNING AND CONTROL

In the most general sense, the aim of manufacturing planning and control (MPC) system is to plan and control all the aspects of manufacturing:

- Material management
- Machines and human resources scheduling
- Suppliers and key customers activities coordination (Jacobs, 2010, p. 1)

Groover (2014, p. 754) divides production planning into three sections:

- Decision which products to make, in what quantity and in what deadline (when the products should be finalized)
- Schedule of the delivery and production of the particular parts and products
- Plan of the manpower and equipment resources required for completion the production plan

According to Groover (2014, p. 754) production planning includes four particular planning activities:

- Aggregate Production Planning
- Master Production Planning
- Material Requirements Planning
- Capacity Planning

Aggregate Production Planning

This activity concerns on planning the production output levels for major products from company product portfolio. These plans must be optimized and coordinated within diverse functions in the company, concerning product design, production, marketing and sales. (Groover, 2014, p. 754)

Master Production Planning

The output from previous section (the aggregate production plan) is to be converted into a master production schedule (MPS) which consists of particular plan of the quantities to be produced for each product line. (Groover, 2014, p. 754)

Material Requirements Planning

Via chapter 1.5.1.1

Capacity Planning

The determination of the human resources and equipment resources needed to achieve the master production schedule. (Jacobs, 2010, p. 242)

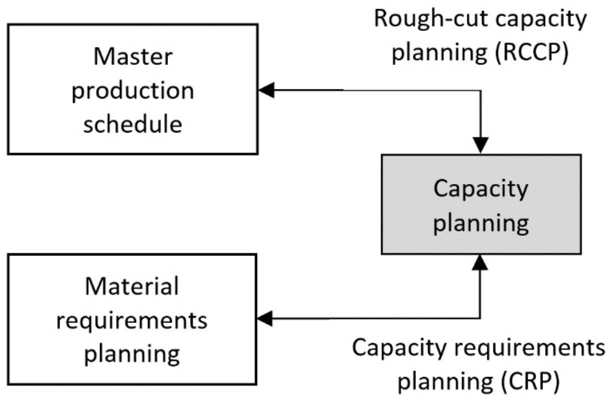


Figure 1 – Two stages of Capacity Planning (own processing according toGroover, 2014, p. 764)

The relationship between production planning activities and other function in manufacturing company is described in following picture:

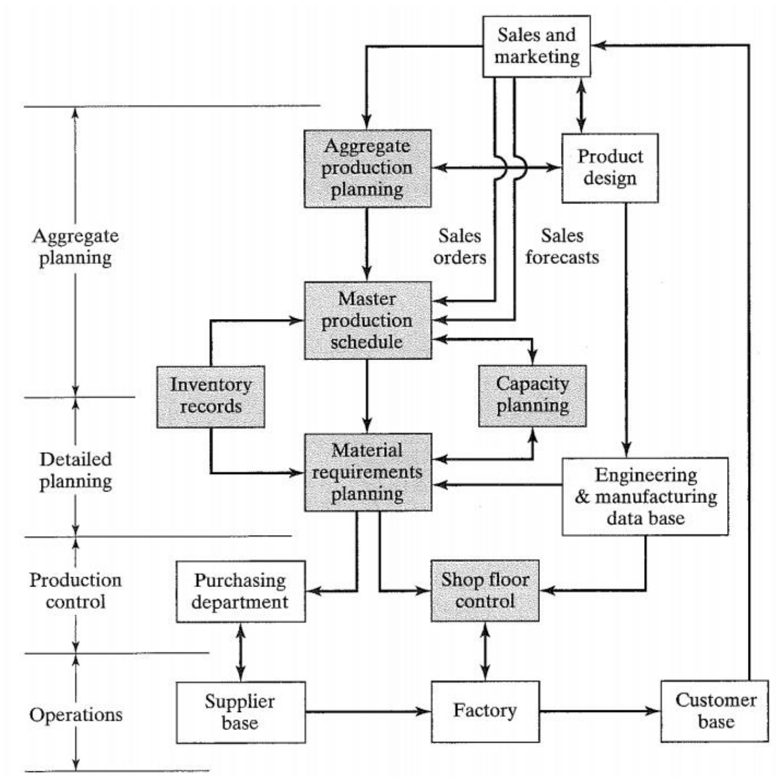


Figure 2 - Activities in a MPC system (Groover, 2014, p. 755)

According to Egri et al. (2004, p. 24) the difference between planning and scheduling is mainly in time period for which is plan or schedule created as well as in level of detail of their processing.

Besides covering various temporary constraints, the solution should respect certain amount of optimization constraints. To find "optimal" solution, scheduling problems require flexible models and efficient, customized solution methods.

Egri et al. (2004, p. 25) points several requirements for solution models and methods:

- Ability to include relevant constraints of production
- The solution should be "optimal" according to set objectives and able to handle unexpected disorders
- The solution methods have to be efficient enough to support interactive decision making
- Possibility of decomposition of production plan into particular schedules that describe production process in its logical arrangement

1.1 Planning

According to Maimon, Khmelnitsky and Kogan (1998, p. 4) the production planning is the process of determining a preliminary plan for the amount of production needed in certain period of time.

The intention of production planning is to create aggregate plan of using resources and material to satisfy customer orders. The production plan encompasses a wide time horizon within months. Productions planning specifies material and capacity requirements for each customer order including setting a date of completing each order. Due to high interactions of material and capacity these requirements have to be optimized and scheduled simultaneously. In consequence the cooperation of following functionalities is needed:

- Material Requirement Planning (MRP I)
- Manufacturing Resource Planning (MPR II)
- Capacity Requirements Planning (CRP) (Egri et al, 2004, p. 24)

1.2 Scheduling

The scheduling provides detail, executable schedules that comply the goals defined by production plans. In the sequence of production activities, the production scheduling lies between production planning and finished products dispatching. (Maimon, Khmelnitsky and Kogan, 1998, p. 4) Therefore, scheduling is entrusted with allocation and execution of final volume of resources to guarantee that all orders can be executed in time and that consumption of resources never exceeds available capacity. (Egri et al., 2004, p. 24)

1.3 Master Production Schedule

The concept of MPS is to translate the sales and operations programme into a plan for producing specific products in the future, concerning their quantities and timing determined. Master production schedule is not a forecast; forecast is an important input for planning process. MPS counts with capacity constraints, production costs, other resource considerations and the sales and operations plan. Master production schedule is an instrument for communication between market and manufacturing. (Jacobs, 2010, p. 153).

According to Harrison and Petty (2002, p. 222) MPS has two functions:

- MPS projects sales and operations plans into manufacturing plans
- MPS serves the purpose of balancing supply and demand

Even the master production scheduling is based on demand (actual or forecasted), it has to take into account product characteristics and various capacities as well. Therefore, MPS the instrument by which management exercise control of the production process. (Harrison and Petty, 2002, p. 224)

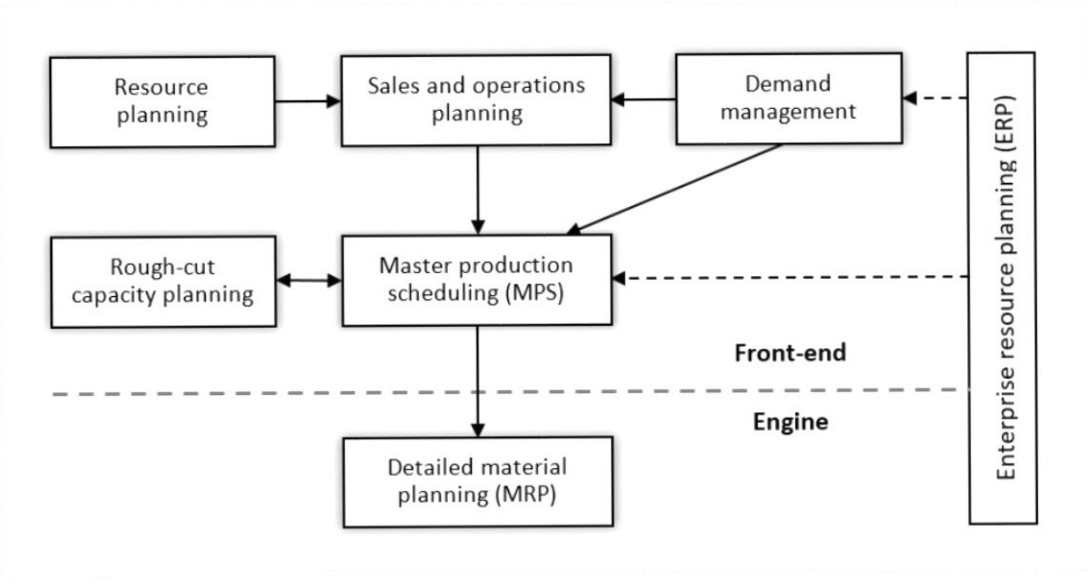


Figure 3 – Master Production Scheduling in MPC system (own processing according to Jacobs, 2010, p. 155)

1.4 Environments of Manufacturing Planning and Control

The production processes can be realized in various environments according to corporate strategy, options and customer needs; these aspects formulate different requirements for the production. Šulová (2009, p. 14) distinguishes between the environments according two aspects:

- Customer Order Decoupling Point (CODP)
- Continuity of the production process

1.4.1 Manufacturing Planning and Control according to Decoupling Point

The Customer Order Decoupling Point (CODP) in the material flow points a moment when production is no longer forecast-driven but starts to be customer-driven. Company can plan and control its manufacturing according to placement of CODP in production process. Thereafter, production strategies are divided into four environments:

- Make-to-stock (MTS)
- Make-to-order (MTO)
- Assembly-to-order (ATO)
- Engineer-to-order (ETO)

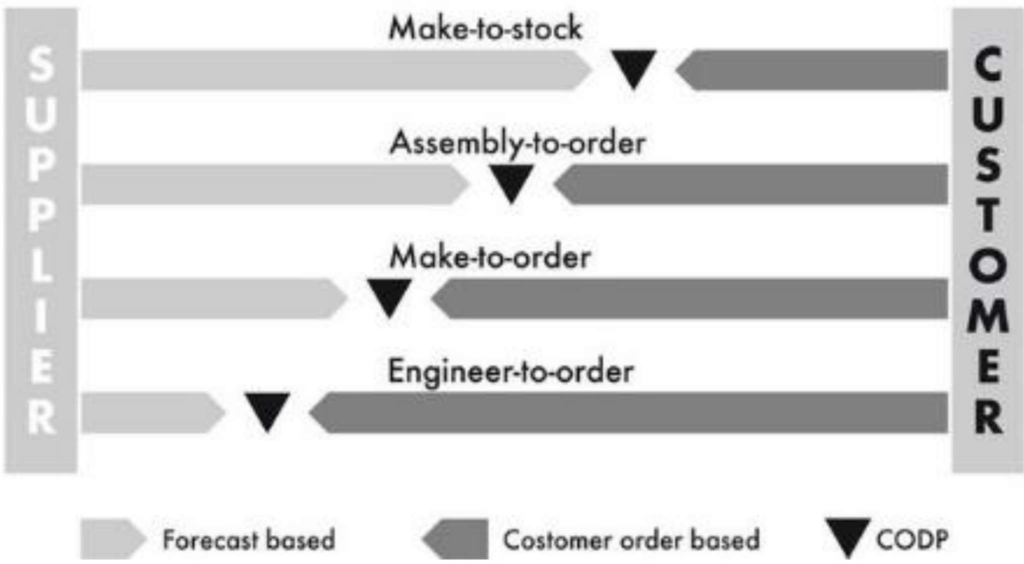


Figure 1 – Customer Order Decoupling Point (Learning with Larry, © 2016)

1.4.1.1 Make-to-Stock

The finished products are delivered to the warehouse and thereafter dispatched to the customer. This solutions can ensure satisfaction of customer standard demand in short time. However in case of special product modification this system is not appropriate since it is wasteful to hold large variety of products. (Keřkovský, 2012, p. 43)

The Make-to-Stock production is adapted to conditions of serial and mass manufacturing, moreover it is appropriate in case of business strategy focusing costs.

Disadvantage of this production strategy is requirement for predictability of customer's demand.

1.4.1.2 Make-to-Order

The Make-to-order system is based on high degree of customization of products. Customer orders are difficult to forecast.

The manufacturing is initiated by receiving customer order. After the order is confirmed, a pull-type supply chain operation starts. (Lean Manufacturing Japan, © 2016)

The MTO system of manufacturing places high demands on purchasing department since it has to be able to act quickly and flexibly in case the preferred supplier cannot deliver the goods. Then it has to look for an alternative in order to ensure material in required deadline. (Software Shortlist, © 2016)

1.4.1.3 Assembly-to-Order

The product is to be assembled after receipt of the customer order. Key components are purchased or stocked according to presumed sales orders. Purchased of the other components and material is initiated by assembly of the product. (SAP, © 2016)

The ATO system is suitable for production based on large number of products that are assembled from widely available components.

1.4.1.4 Engineer-to-Order

This approach is similar to MTO but customer also expect substantial level of engineering and designing from the side of manufacturer. Each product is unique and requires special bill of material and components which are purchased for a specific final product. (Benton, 2014, p. 11)

For ETO are typical long lead times within months and high prices corresponding to the demands of production.

1.4.2 Manufacturing Planning and Control according to Continuity of the Production Process

This chapter deals with problematics of continuity of the production process. According to Tuček and Bobák (2006, p. 48) commonly used division of the production process is into two categories:

- Discrete manufacturing
- Process manufacturing

In association with production process classification in terms of information systems the third category is added – cellular (line) manufacturing. (Šulová, 2009, p. 17)

1.4.2.1 Discrete Manufacturing

The discrete (discontinuous) manufacturing is characterized by time breaks in production process. Production interruption is caused by non-technological processes as material transport, clamping and removal of a product, dies exchange etc. Technological processes form a small part of production lead time. Discrete manufacturing is demanding mainly due to the considerable diversity of operations and assortment extensiveness. (Šulová, 2009, p. 17)

Vollmann (2005, p.) submits following signs of discrete manufacturing:

- Wider range of products
- Higher production costs
- Difficult process automation

Sodomka and Klčová (2010, p. 251) determine other important features in terms of modern information systems:

- Flexible inputs planning
- MTS and MTO support
- Total cost evaluation
- Simulation of costs for individual products
- Production data quality improvement

1.4.2.2 Process Manufacturing

The process or continuous production is realized without interrupting production time with any machine stop even in case of material feed during production. Continuity is also given by the fact that start of the production is associated with considerable costs. Due to mass-production character this continuous manufacturing is ideal for production process automation. Therefore, in these productions a high level of automation is achieved. (Melčák, 1999, p.38)

1.4.2.3 Cellular Manufacturing

As Hrušecká (2015, p. 12) states, cellular manufacturing has both characteristics of discrete and process manufacturing. The production process is divided into several autonomous lines (cells), in which material flow is continuous, however, sequencing of individual cells has form of discrete manufacturing.

1.5 Manufacturing Planning and Control in Information Systems

With the advent of computers, simple enterprise software came into being. The first genuine software applications were systems for monitoring and controlling finance and accounting, which were extended by inventory and assets control in 50s.

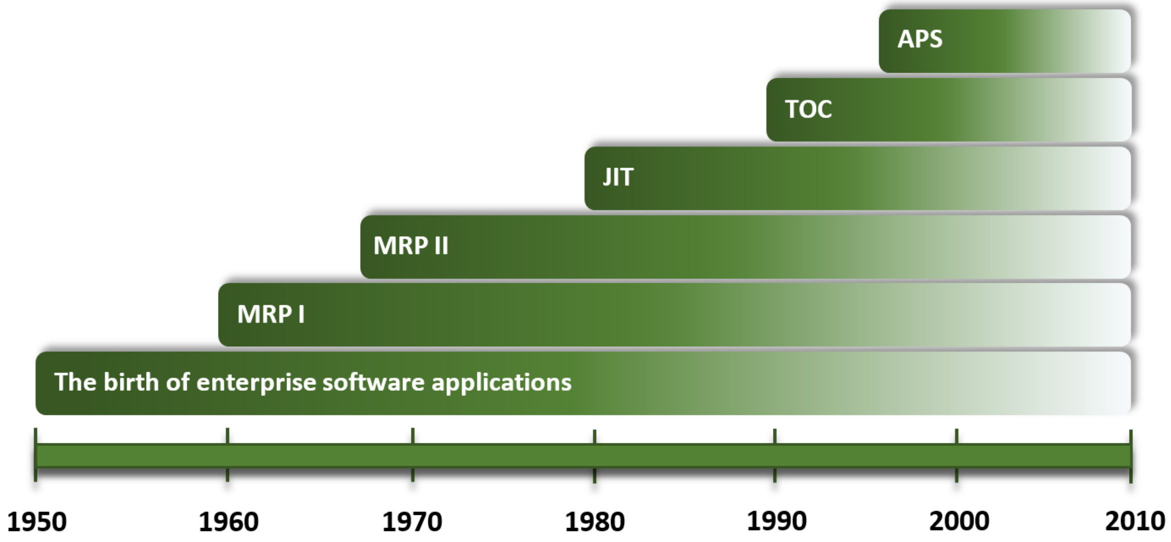


Figure 4 – The Evolution of MPC systems in Information Systems (own processing)

The birth of ERP systems using computing technology is dating from the early 60s. This era of "Resource Planning Systems" initiated manufacturing companies to require automated planning of material consumption (MRP I – Material Requirements Planning).

By the beginning of 70s, the first software corporations start to rise. Those are SAP in 1972 and Lawson Software in 1975 – the aim of this corporations is to offer standard enterprise applications able to integrate core processes.

Since 1976, MRP system are extended with functionality of production management. By the end of 70s, the original concept of MRP is enhanced of all manufacturing resources planning – MRP II (Manufacturing Resource Planning).

In 80s, "push system" of MRP II is enlarged with "pull" method of Just-in-Time (JIT) based on well-timed delivery of goods according to customer's requirements. This conjunction of push and pull systems caused the rise of the ERP (Enterprise Resource Planning) systems which reflect material requirements, deadlines and capacities including financial and other resources.

By the beginning of 90s, the idea of ERP is supported in connection with functionality enlargement of human resource management and project management. (Sodomka a Klčová, 2010, p. 185-189)

1.5.1 Traditional Approach

The Material Requirements Planning (MRP I) and Manufacturing Resource Planning (MRP II) can be identified as the approaches of traditional production planning and scheduling. These concepts are based on "push principle" causing several difficulties for planning such as no capacity consideration, no lead time and cost optimization etc.

1.5.1.1 Material Requirements Planning

The MRP concept is more focused on inventory management than on production planning. The very essential idea of MRP is to substitute formerly widely used standard driven inventory management with more effective way based on targeted material orders according to actual production needs. (Keřkovský, 2012, p. 77)

The structure of MRP system is described in following picture:

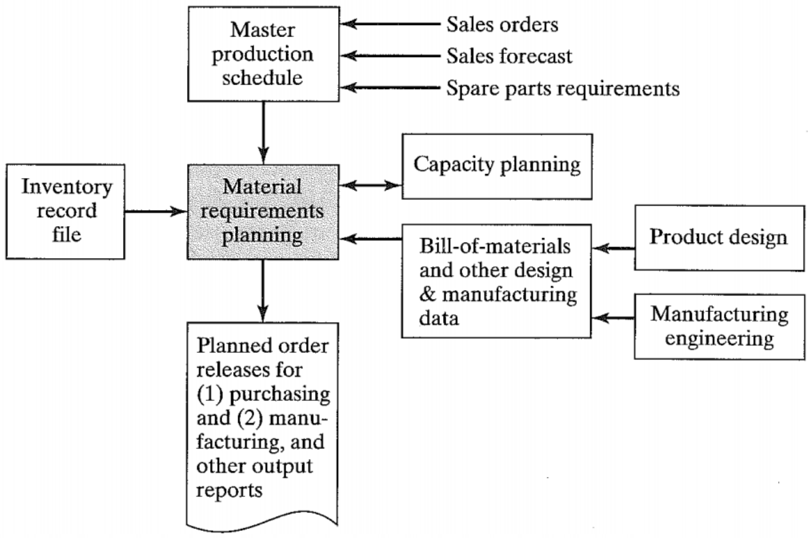


Figure 5 – Structure of MRP system (Groover, 2014, p. 758)

The Material Requirements Planning is based on computational procedure in order to convert the master production schedule for final products into a detailed schedule for raw materials and components used in the final products. This detailed schedule points the quantities of each item concerning deadline of the delivery as well as its placement in order to implement the master schedule. (Groover, 2013, p. 1044). Jacobs (2010, p. 183) states the requirement planning in MRP concepts is characterized by the use of period-by-period requirement records. This time-phased approach to planning makes MRP to be „the cornerstone" concept for material planning and control.

According to Daněk and Plevný (2005, p. 98), disadvantages of MRP I are as follows:

- Concept of MRP I does not optimaze material purchase costs
- No quantity discount shall be calculated which leads to costs increase
- The risk of slowdown in production caused by supply delays has to be controlled by emergency stock

1.5.1.2 Manufacturing Resource Planning

The Manufacturing Resource Planning (MRP II) is substantial extension of MRP I improved by connection of material orders concerning detailed master production schedule with capacity calculations. MPR II system is integrated in majority of business software for production management. (Keřkovský, 2012, p. 78)

Daněk and Plevný (2005, p. 100) pointed out the disadvantage of MRP II. In the initial stage of planning process, this concept does not count with capacity constraints. In case of discrepancy of resources with requirements, it is necessary to solve this problem out of the system and to redo calculations.

1.5.2 Modern Approach

The planning concepts included in so called "modern approach" are based on "pull principle" in which is production process initiated by customer order. Just-in-Time concept (JIT) is genuine example of "pull" manufacturing. Whereas, there are situations where it is not appropriate to follow "pull principle" in production process. Sometimes it is necessary to combine "push" and "pull" to achieve the desired results. In such cases, the concepts of TOC (Theory of Constraints) and APS (Advanced Planning and Scheduling) are suitable methods for production planning and scheduling.

1.5.2.1 Just-in-Time

The production planning approach of Just-in-Time (JIT) is based on so called Kanban method. Both of these philosophies come from Japan.

According to Sodomka and Klčová (2010, p. 257), JIT is pull principle under which the manufacture of the product is initiated by the customer. All the required components are yet "in time" driven thru business processes to final assembly and product delivery to the customer. The JIT based manufacturing involves supplying the material, products and services in terms that are needed to execute the particular production processes that directly respond to customer demand. The level of mastering the JIT in an organization can be measured by the achievement of "seven zeros". (Gregor a Košturiak, 1994, p. 27)

- Zero defects
- Zero set-up time
- Zero inventories
- Zero handling
- Zero breakdowns
- Zero lead time
- Lot size of one

Kanban

The Kanban system is one of the main representatives of “pull” principle. It serves as a tool for fine-tuning the production and interconnection of individual processes. Taichi Ohno introduced it at the Toyota Company in 1953 in order to optimize inventory in the serial production.

The name “Kanban” comes from the Japanese words “kan” (card) and “ban” (signal). This is a Japanese system of the workshop production management. The essence of the Kanban concept is based on providing only those components from the supplier, warehouse or floor shop that are needed in a given amount and at any given time so that there is no excess inventory. Kanban principle is based on the assumption of possibility to divide the work to vendors and customers with strictly defined circle of workplaces that deliver and collect the material. The labels (kanbans) inform about the resource requirements of the particular workplaces. These Kanban cars circulate within individual workshops. (Šimon a Miller, 2014, p. 21)

1.5.2.2 Theory of Constraints

The author of Theory of Constraints (TOC) is Eliyahu Moshe Goldratt. TOC is based on the assumption that each system has its own limitations and constraints that prevent the achievement of goals (in business practice, the goal is to make money). In the industry, the attempt is to maximize the flow thru bottleneck. Goldratt (Cíl: proces trvalého zlepšování, 2001) Cox and Schleier (Theory of Constraints Handbook, 2010) divided TOC implementation into five following steps:

1. The identification (choice) of the system constraint
2. The decision how to exploit the system constraint
3. The subordination of all other decisions to the above
4. The elevation of the system constraint
5. When the constraint is broken, going back to step 1

For the evaluation and monitoring of these stated goals, the metrics have to be determined. In business practice, Tuček and Bobák (2006, p. 92) state following metrics that are commonly used:

- Throughput – the selling price lowered by total variable costs
- Inventory – the value of materials and goods held by the company

- Operating Expense - money spent on transformation of inventories in selling products

The relationship between financial metrics and TOC metrics is described in following picture:

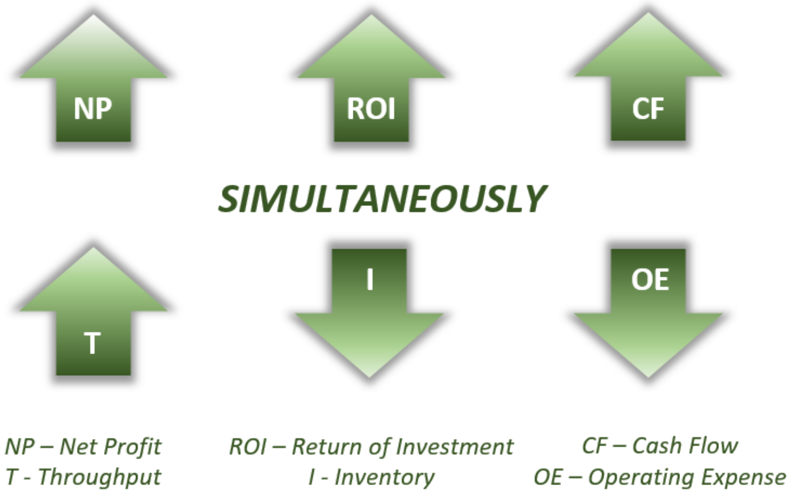


Figure 6 – The Financial and TOC metrics relationship (own processing according to Tuček and Bobák, 2006, p. 93)

Drum-Buffer-Rope

To ensure maximal flow thru bottleneck, the production process is coordinated with Drum-Buffer-Rope (DBR) approach of production flow management. DBR is based on regulating the input of production tasks in the production system according to the progress of operations in the bottlenecks. The bottleneck sets the pace of the entire production system. The bottleneck is connected to the input material in the production system with the "ropes" (the rope is the information flow from the bottleneck to the input). If any resource before the bottleneck is dropped, the performance of the bottleneck could be compromised, therefore, the critical resources are "protected" in a "time buffer". (Košturiak a Frolík, 2006, p. 55)

1.5.2.3 Advanced Planning and Scheduling

Via chapter 3.

1.5.3 Enterprise Resource Planning

The term ERP (Enterprise Resource Planning) was introduced as a successor of the earlier terms MRP I and MRP II. These predecessors were focused on material and resource planning for the production processes, however the idea of ERP is to consider and to include all resources needed for the success of the enterprise. (Kurbel, 2013, p. 95)

The development of ERP is driven by two approaches:

- The manufacturing company performs its activity within business processes involving several business functions. Some of these functions are related to manufacturing directly, other functions are focused on human resources, marketing, controlling etc. Consequently, there is the need of integration all these function into one enterprise resource planning. (Kurbel, 2013, p. 95)
- The development of ERP is determined by the need of effective information sharing and providing not only within the company but also in the context of suppliers and customers.

According to Sodomka and Klčová (2010, p. 73), the business information systems are divided into four levels described in following picture:

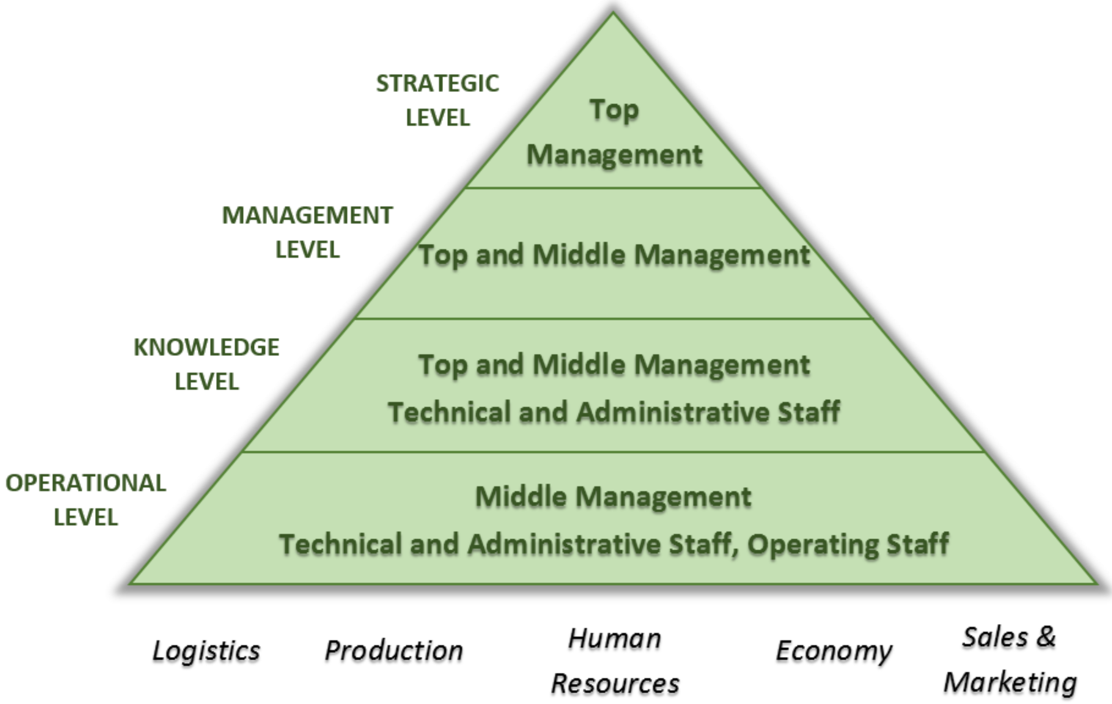


Figure 7 – Information Pyramid (own processing according to Sodomka and Klčová, 2010, p. 74)

Sodomka and Klčová (2010, p. 77) divide the business information system into four subsystems according to holistic-process classification:

- The ERP core focused on internal business processes

- The CRM (Customer Relationship Management) for operating processes directed to customers
- The SCM (Supply Chain Management) with integrated APS
- The MIS (Management Information System) for the data collecting from ERP, CRM and SCM/APS subsystems and for providing information for decision-making process of corporate management

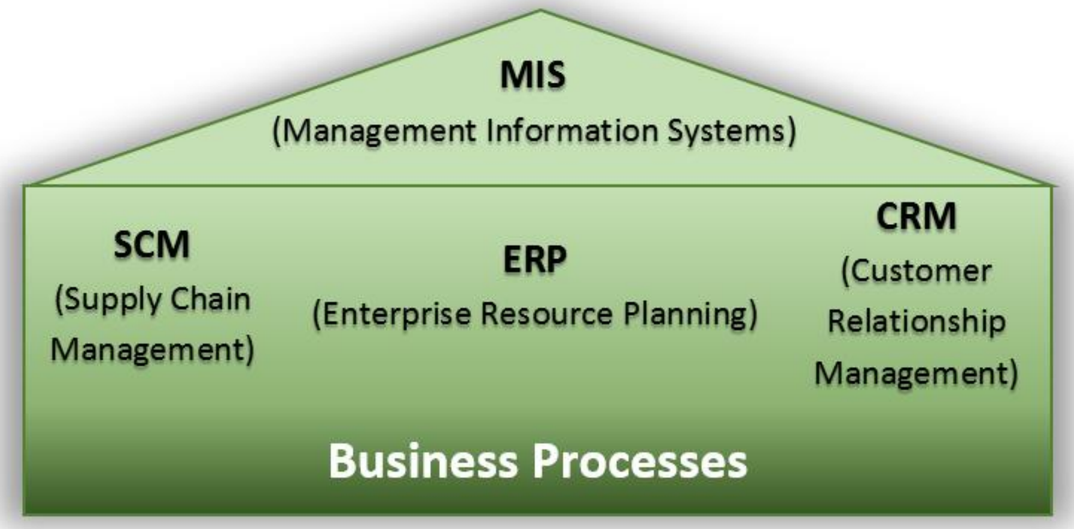


Figure 8 – Systems Integration (own processing according to Sodomka and Klčová, 2010, p. 78)

Many companies use for their activities more separate information systems (e.g. one for production management, the other for logistics, distribution, asset management, sales, billing, accounting, human resources, etc.) instead of one integrated. Once the company has a variety of interconnected information systems, there is an automated data sharing, which facilitates and speeds up its manufacturing and distribution processes.

According to data from Český statistický úřad (© 2016), for the evaluation of the internal processes integration level it is commonly distinguished between ERP and CRM information systems:

- 30 % of Czech companies used ERP application in January 2015 (21 % in 2010)
- 23 % of Czech companies used CRM application in January 2015 (15 % in 2010)

Both of these applications are often used by large companies (250 and more employees):

- 82 % used ERP

- 47 % used CRM

The survey of Český statistický úřad (© 2016) conducted among the large corporations states:

40 % of companies use only ERP application

- Over 80 % of Czech large companies use ERP application
- 47 % of Czech large companies use CRM application
- 13 % of Czech large companies does not use ERP or CRM application at all

For detailed information about utilization of ERP and CRM in Czech large companies see following diagram.

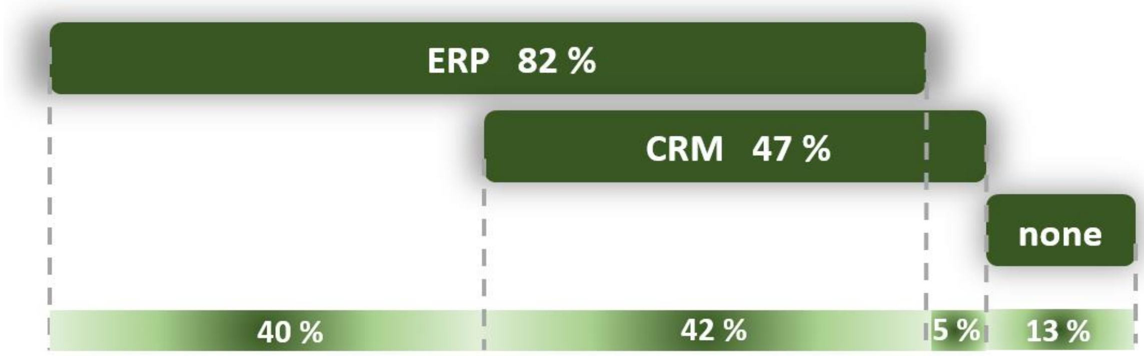
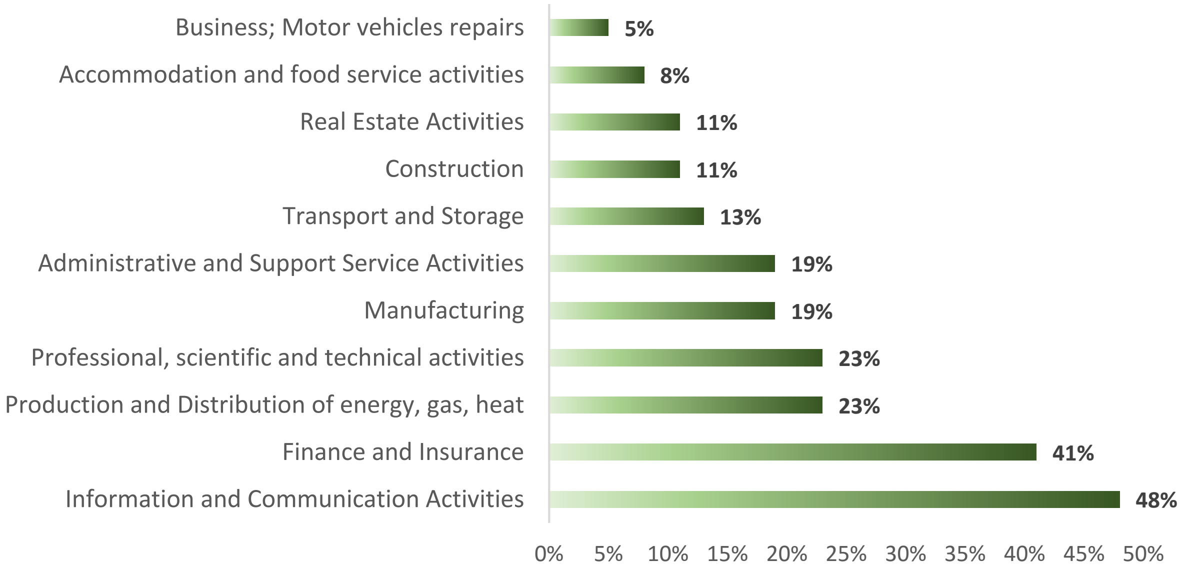


Figure 9 – The Rate of ERP and CRM Deployment within Large Corporations (own processing according to ČSÚ, © 2016)

The highest utilization rate of corporate information systems was registered in the area of information and communication activities and in the field of finance and insurance. Surprisingly, quite low utilization rate of corporate IS was registered in the manufacturing industry and administrative. The lowest utilization rate is registered in the business area.

Chart 1 - Utilization Rate of Corporate IS according to Business Sectors (own processing according to ČSÚ, © 2016)



According to Svatá (2007, p. 6) despite of the considerable evolution, the ERP systems completely failed to meet the expectations (based on many applications and statistics). The most cited deficiencies of ERP follows:

- The mismatch between product functionality offered and the needs of users
- Expensive maintenance
- Great dependence on an external supplier and the system
- The complexity of integration with other systems and its continuous adaptation with new versions of the system.

2 ADVANCED PLANNING AND SCHEDULING

The advanced planning and scheduling (APS) is a generic designation for modern methods and algorithms that utilize information and communication technologies (ICT) and software applications to simulate, optimize and streamline the production planning and logistics processes. The APS helps to compute complex scheduling algorithms concerning a whole range of other factors; this computing would not be possible in a real time without ICT utilization.

2.1 Structure of the Advanced Planning and Scheduling System

The Advanced Planning and Scheduling (APS) offers support for long-term, mid-term and short-term planning of the supply chain consisting of the sections:

- Procurement
- Production
- Distribution
- Sales

According to Neumann et al. (2002, p. 45), the limited availability of resources is considered in all planning phases. The supply chain planning is infeasible due to the complexity and size of the particular decision problems. The different planning horizons prompt a division into long-term, mid-term and short-term planning. That's why APS is usually disintegrates into planning modules where the interdependencies between individual modules have to be respected.

Quadt (2004, p. 2) characterizes the planning horizons as follows:

- Long-term production planning comprises the seasonal demand fluctuations on an aggregate basis. Time period is to several years.
- Medium-term production planning covers the detailed planning of finished products with short-term forecasted inputs. Time period is to several months.
- Short-term production planning consists of lot-sizing and scheduling in period of weeks.

Figure 10 shows the structure of a generic APS (De Santa-Eulalia et al., 2011) consisting of modules for the phases:

- Strategic Network Planning (Design)
- Demand Planning
- Supply Network Planning
- Production Control
- Transportation Control
- Demand fulfillment
- Inventory Management

Each box in *Figure 10* corresponds to a module of the APS. The darts between boxes represents information flows between modules.

The **Strategic Network Planning** module deals with the structure of supply chain, therefore copes with planning locations of floor shops and warehouse and with designing the layout of individual floor shops. Concerning manufacturing industries, network design reflects whether it is manufactured in continuous, semi-continuous or batch production mode. Floor shops operating in continuous mode are intended for one product group. In semi-continuous mode, the processing unit is fed with inputs continuously and the outputs emerge discontinuously (or vice versa). Batch mode is typical for production where small amounts of a large number of products are required. (Neumann et al., 2002, p. 46)

Wagner (2000) states, the **Network Planning** module depends on long-term changes in production programme, therefore the inputs are long-term forecasts for potential sales which ensue from the **Demand Planning** module, which operates in three steps:

- Statistical forecast that captures the main characteristics of time series of the past and creates forecasts using time-series analysis and casual models
- Addition of the information into the time series that had not been included into statistical forecasting
- Cooperation between different functional areas to get a consensus on the forecast

According to the APS structure described in *Figure 10*, **Supply Network Planning** module disintegrates into three submodules:

- Aggregate Planning
- Synchronized Production-Distribution Lot-Sizing

- Material Management & Procurement Planning

The **Supply Network Planning** focusses on efficient utilization of production capacities specified by the Network Planning module. Processes performed within this module are based on mid-term forecast (for at most one year) including fixed customer orders, the effects of marketing campaigns and sales promotions. All the information has to be considered in the planning procedure in Supply Network Planning module. (Neumann et al., 2002, p. 49)

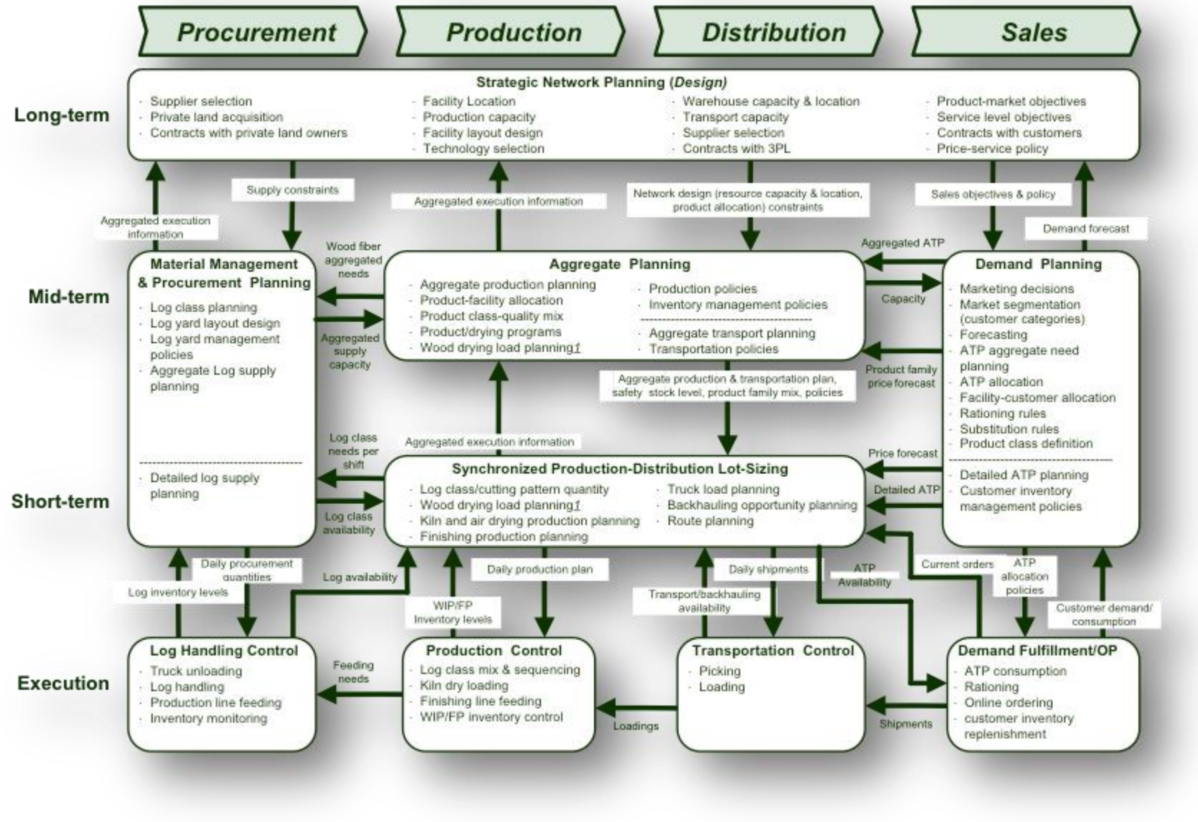


Figure 10 - Structure of APS (De Santa-Eulalia et al., 2011)

2.2 Concepts

The fundamental decision in manufacturing process planning is to formulate general concept. Šulová (2009, p. 41) submits list of concepts:

- Available-to-promise (ATP)
- Allocated-available-to-promise (AATP)
- Capable-to-promise (CTP)
- Profitable-to-promise (PTP)

2.2.1 Available to Promise

The approach of ATP is straightforward concept of sales management. ATP is standardly used in MTO production environment. Acceptance of sales order is conditioned by availability of product in warehouse.

2.2.2 Allocated Available to Promise

The AATP extends Available-to-promise concept of additional criteria evaluation. Finished production delivery is performed in accordance with classification of customer's credit and location.

2.2.3 Capable to Promise

The significant extension of previous concepts is CTP which takes into account situations when product is not available in warehouse.

In such cases this approach of planning focuses on limited production capacity, material and other resources which availability is subsequently examined. (Šulová, 2009, p. 43)

CPT is utilized in production environments of MTO, ATO and ETO.

2.2.4 Profitable to Promise

The increasing planning efficiency represents concept of PTP involving orders comparison by their profitability. Profitability is calculated as price the customer is willing to pay decreased by sum of costs expended to secure the product. (Šulová, 2009, p. 42)

PTP is suitable for all production environments (MTS, MTO, ATO and ETO).

2.3 Planning and Scheduling Models Formalization

All the planning and scheduling algorithms are based on formal system description so called **model**. The model is constituted by distinguished processes; each particular process is characterized by set of attributes (duration, costs, profits, tariffs, resources requirements, tact time etc.). The relationships between particular processes are defined within the model, e.g. the beginning of the process is conditioned by the end of the previous one. The system formalization depends on general planning intention of the planner. The algorithm does not consider the internal structure of the processes.

2.4 Algorithms

Concerning the issue of production planning, the term “algorithm” is perceived as a procedure leading to solution of an optimization problem based on a formal model of the optimized process. In economic practice, there are mostly linear models, e.g. models for which the objective function and constraining conditions are formulated with linear functions.

Complexity of the Optimization Problem

The complexity of some algorithms can be so great that not even the most powerful computers are able to provide a result within a reasonable time (a sufficiently short time for a practice). Usually used method for such problems are those which, although, does not provide an exact solution but rather find a solution accurate for the purpose.

The following list of algorithms represents the summary of mostly used approaches for planning and scheduling tasks solutions.

2.4.1 Shortest Path Algorithms – Critical Path Method

The Critical Path Method (CPM) is applicable to planning the processes carried out on technologically precisely defined place. The precondition of CPM application is knowledge of process times of particular activities.

The CPM provides the oriented diagram with the edge evaluations. The edges represent particular production activities. The activity characterized with the edge-based node should be initiated only after the completion of the activities that enter this node.

Therefore, Kolčavová (2010, p. 130) states the method provides an overview of the time characteristics of each activity:

- Earliest start time
- Earliest finish time
- Latest start time
- Latest finish time

2.4.2 Linear Programming – Simplex Method

The Simplex method is applicable in tasks with linear objective function and restrictive conditions formulated with linear inequalities.

The Simplex method is an iterative computational procedure for finding the optimal solution for the task of linear programming problems. The starting point of this algorithm is to find initial basic solutions for the task of linear programming. Thereafter, the simplex method calculates always new basic solution with improved value of the objective function (for maximization – higher value of the objective function, if minimization - lower value of targeted function). After a finite number of steps this computational technique leads to find basic solution with the best value of the objective function or to find that such a solution does not exist. (Kolčavová, 2010, p. 32)

2.4.3 Dynamic Programming – Bellman-Ford Algorithm

The optimization problem techniques of dynamic programming are based on so called Bellman's optimality principle which decomposes the optimization problem into smaller subproblems, therefore the optimal solution is constructed from optimal solutions of these subproblems. (Brucker and Knust, 2012, p. 100)

The typical optimization problem solved with dynamic programming is so called Knapsack Problem.

2.4.4 Heuristics Methods

To solve the difficult problem it is expedient not to seek the optimal solution, but overcompensates randomly chosen solutions, while the selection of such a solution can be controlled by some other unspecified rules. Choosing the solution may depend on personal experience of the solver, or it can be controlled by appropriately chosen formal procedures. In this case the genetic algorithm is usually used.

2.4.4.1 Genetics Algorithms

The genetic algorithm transforms a set of abstract entities being characterized with an associated fitness value, into a new set of entities (e.g., the next generation) performing operations based on the principle of biological reproduction (crossovers) and Darwinian survival - the fittest entities participate on the further evolution. (Koza, 1992, p. 18)

Within the genetic programming, some structures undergo adaptation so they become general, hierarchical computer programs of dynamically varying size and shape. (Koza, 1992, p. 73)

II. ANALYSIS

3 KOVÁRNA VIVA A.S.

Kovárna VIVA a.s. was established in 1992. Then, Kovárna employed 36 employees, who manned three forging units. In next few years, forging production boomed and in 2000 VIVA has its first foreign customer. In 2016 Kovárna VIVA a.s. ranks among the best Czech forging shops specialized in closed die forging. (Internal materials)

Figure 11 – Corporate Logo and Corporate Philosophy (internal materials)

3.1 Certificate of Incorporation

According to business register (Justice.cz, © 2016):

Date of registration: 27th October 1992

Business name: Kovárna VIVA a.s.

Company residency: Vavrečkova 5333, 760 01 Zlín, Czech Republic

Registered identification number: 469 78 496

Legal form: Joint-stock company

Scope of business: blacksmithing, farriery, metalworking, production, trade and services

Basic capital: 50 000 000 CZK

Paid: 100 %

Number of employees: 390

3.2 Corporate Philosophy

The vision of Kovárna VIVA a.s. is to produce exceptional and technically superior products. The company puts emphasis on good customer relations based on trust. The long prosperity is ensured through employee development, continuous improvement of processes and improving the internal and external environments.

3.3 Organizational Structure

The intention of efficient corporate management is based on division of the management into several organizational structures.

This project has been specified by the logistics department, which belongs directly to CEO.

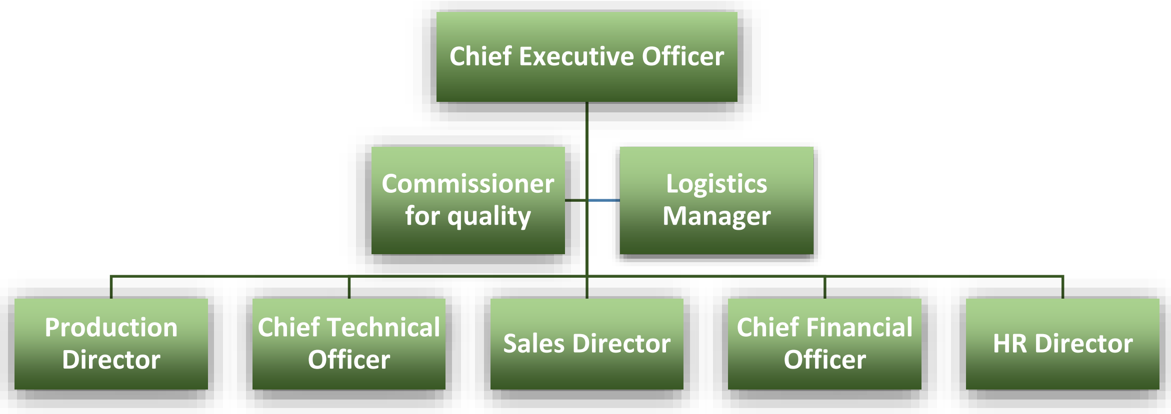


Figure 12 – Top Management Organizational Structure (own processing)

3.4 Production

All the processes performed by the company are conducted in accordance with legal standards:

- ČSN-EN ISO 9001
- ČSN-EN ISO 14001
- TS 16949

The production process consists of particular operations sequence. In general, the first part of production is illustrated in so-called **Input Section**, followed by **Material Cutting** section from which the material enters the section of **Forging**. After the forming processes, the forgings continue to **Heat Treatment** section followed by **Shot Blasting**. Before entering the section of **Metalworking**, the semi-finished products have to pass the **Input Section** again. After metalworking, products continue to so-called **Finishing Operations** including handling, storage, packaging and dispatch. The production flow is described in following picture.

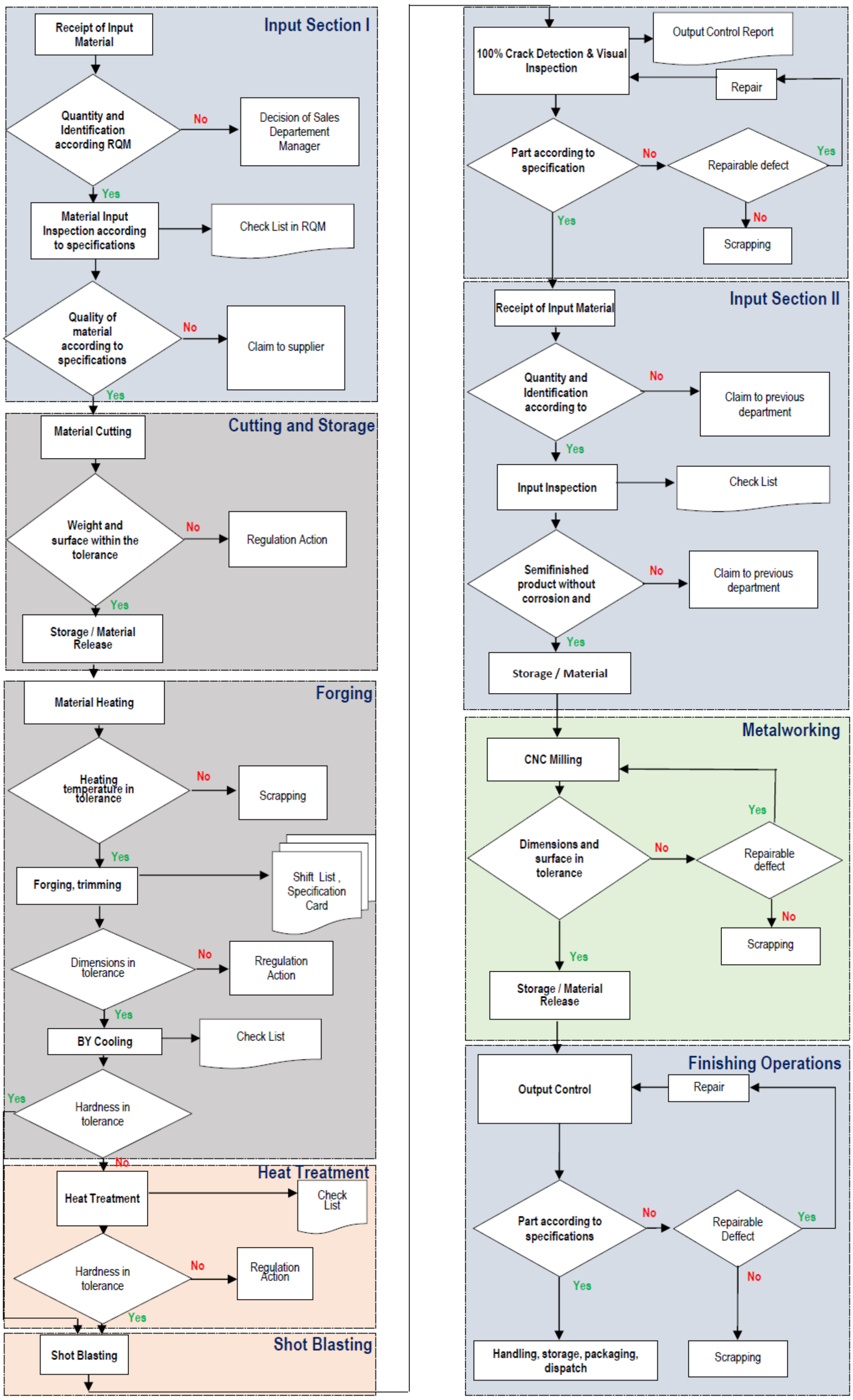


Figure 13 - Process Flow Diagram (internal materials)

4 CURRENT STATE ANALYSIS

4.1 The Business Strategy

The business strategy of Kovárna VIVA a.s. has characteristics of MTS, MTO and ETO production environments and corresponds to concept of CTP. Within the planning process analysis, the attention is focused on production scheduling taking into account available capacities and resources. The activities related to the product development and design are not taken into consideration.

4.2 Corporate ERP – ABAS

Due to the business strategy mentioned above, Kovárna VIVA a.s. decided to use the product of ABAS Software AG with headquarters in Karlsruhe in Germany. The representative for Czech Republic is amotIQ s.r.o. headquartered in Prague.

Figure 15 - abas logo (abas system gmbh, ©2012)

Figure 14 – amotIQ logo (amotIQ, ©2007)

Abas ERP is suitable for small and medium-sized companies engaged in manufacturing and for distributors. Currently, three abas application are offered:

- Abas ERP
- Abas Distribution
- Abas eB (e-Business solution with access through the internet)

The software has a broad set of functionalities:

- Production planning and control
- Warehouse management
- Inventory management
- Purchase and procurement
- Service

- Customer relationship management (CRM)

Once the company integrates all of these functionalities, the business is allowed to optimize the activities of customer service, minimize lead times a cycle times of particular production processes and improve the inventory management.

All the significant modifications are consulted and implemented with the vendor directly.

Companies that decide to purchase abas will deal with the vendor directly for the sale and implementation of the system. In terms of implementation, abas heavily favors the Linux operating system with more than 3/4 of the installations of abas taking place on the open source technology. However, the software is also compatible with Windows for companies that are not inclined to use Unix family platform.

To provide users with all the necessary information, abas functionality is distinguished into modules:

- Customer Relationship Management
- Sales
- Purchasing
- Material Requirements Planning
- Sales Planning
- Production
- Service Processing
- Costing
- Financial Accounting
- Cost Accounting
- Group Accounting
- Fixed Asset Accounting

The data are accessible through several information systems. Each information system displays data from a certain part of the database. The individual information systems enable to visualize the contained data using a variety of visualization tools, e.g. the Gantt diagram, flow charts, etc.

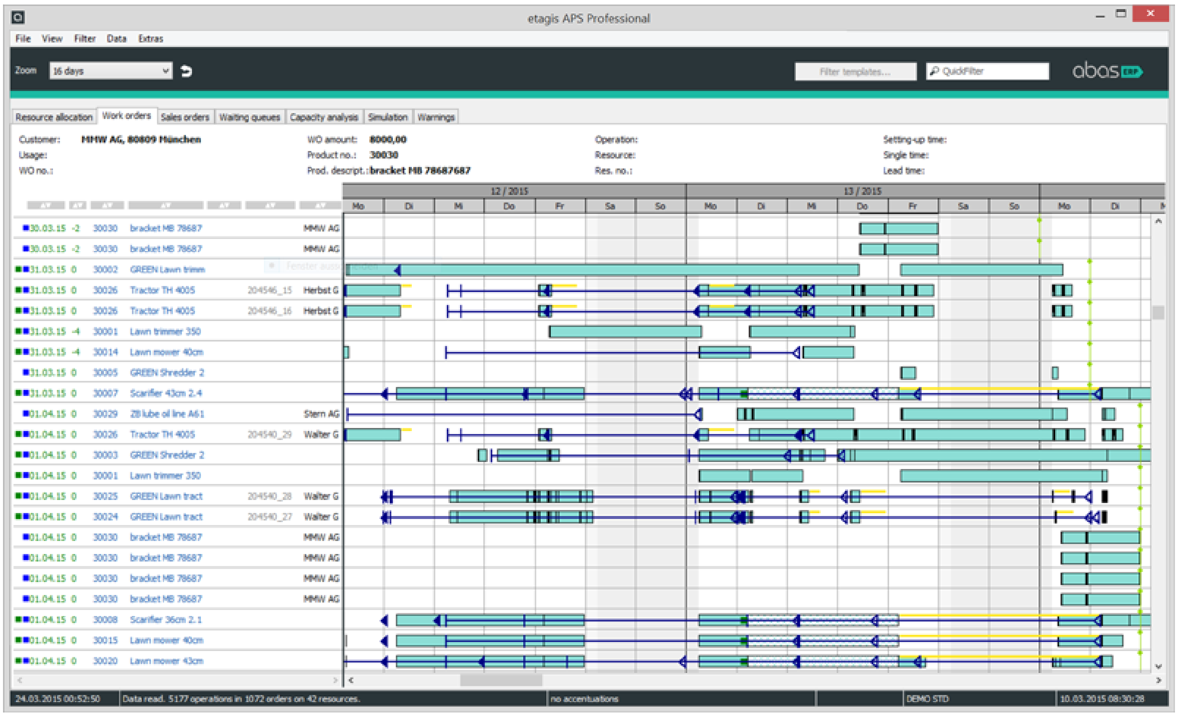


Figure 16 – Example of the Schedule Visualization (abas ERP, ©2016)

4.3 Planning and Scheduling Process

The current planning and scheduling activities are based on significant knowledge and experience of a planner. Actual practice even requires planner to fyzicaly enter data acquired from tool shop and forge shop managers.

The planner prepares the schedules by ad hoc manipulation with the order items in order to schedule the production of particular articles in a such way that enables to keep the same article types in a sequence. The line utilization is scheduled to reach the working ratio, habitually set at the value over 100 % to reach statistically average machine utilization close to 100 %. This statistical drop of utilization is typically caused by cancelation due to some technologicall and organizational failures.

Key Managing Persons for the Planning and Scheduling Processes

The production organization is controlled by following persons.

- Dispatcher
- Planner
- Buyer
- Tool shop manager
- Forge shop manager

Each of the users have its defined role in planning and scheduling process. The activities performed by each user are described in particular flow diagrams. In general, the flow diagrams are divided into two basic areas:

- The left side of the diagram presents the direct human activities of each ERP user
- The right side of the diagram shows the supporting operations executed by ERP

The information flows between both areas are symbolized by arrows, there are two types of arrows:

- Solid line represents the real data flow from the user to the ERP
- Dashed line indicates the output from ERP giving user relevant information for his decision-making processes

In specific occasions, the dashed line indicates the request issued by ERP to execute some human activity of the ERP user, e.g. the buyer obtains a request to buy a material.

All the diagrams are drawn in accordance to standard ČSN ISO 5807.

Dispatcher

The dispatcher communicates with customers and accepts all their orders. These orders are than formalized as an input data for the ERP. The only checked order attribute is the article. In case the article has never been produced yet, the customer order is refused. Such situations are usually handled as special development task. Within the dispatcher role, no expert assessment is carried out.

As a consequence of such lack of assessment is that many orders appear to be unrealizable within the given deadline. Another problems arises while the order enters the ERP. In the moment when many orders are entering the ERP simultaneously, the required resources appear available until the orders are processed by the planner who such cases face the problem of insufficient amount of material in the stock. This system of order processing appears to be insufficient for the effective planning. Therefore, it is necessary to enlarge the dispatcher activities with the order feasibility assessment.

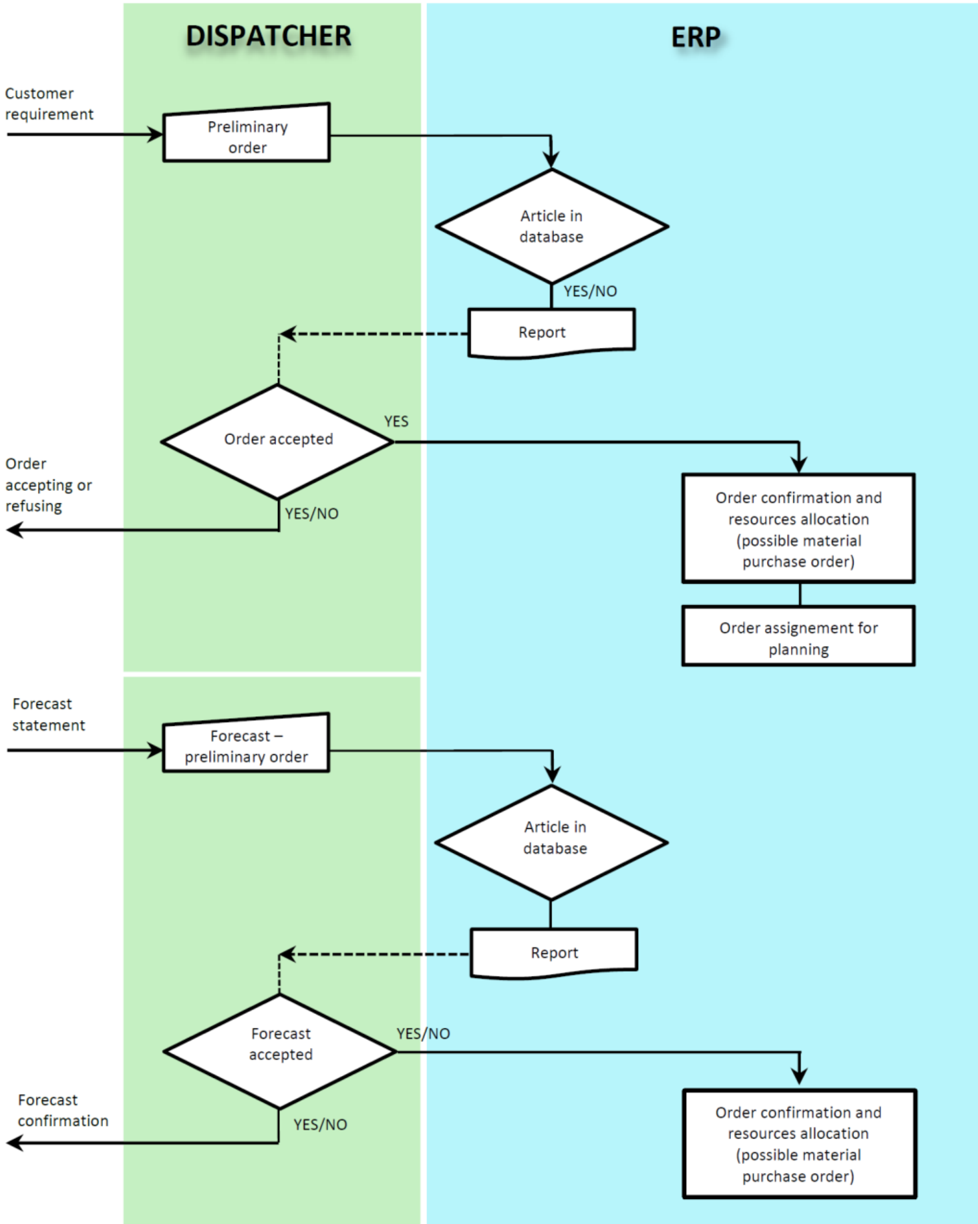


Figure 17 – Current Dispatcher Workflow (own processing)

Planner

The main managing role is performed by the planner, who check the plan feasibility and control the availability of particular resources. The major source of information for planner's decision making process is the face-to-face communication with the cooperating staff members. The ERP is used to get all the information regarding orders and also it is utilized for the schedule completion. The result of planner decision making process are particular requests for next cooperators.

The planner is the only real user of the ERP. He has strictly defined the user authorization and responsibilities.

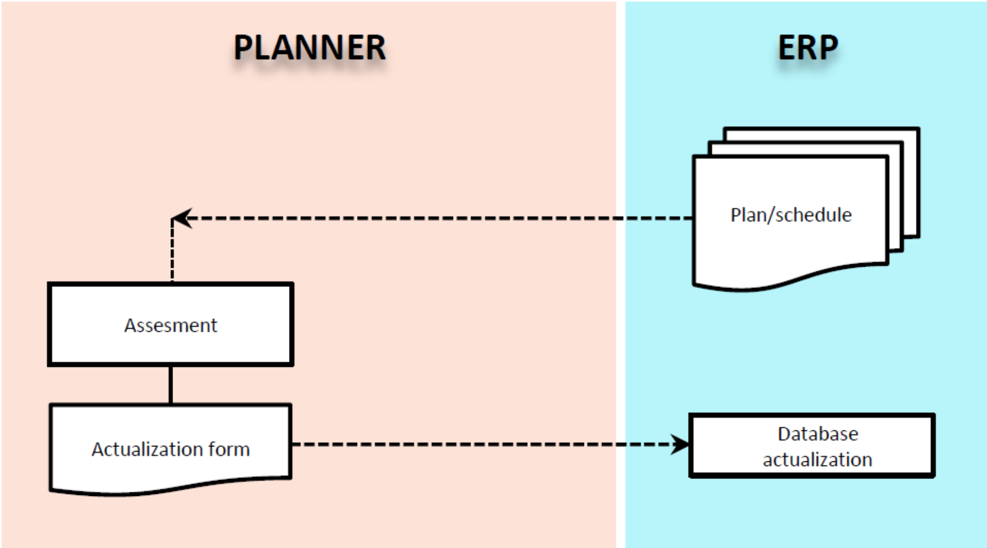


Figure 18 – Current Planner Workflow (own processing)

Buyer

The buyer's job is to ensure any material in required deadlines. The part of a material can be received in the stock in accordance of the forecast. However, the operational activities have to be consulted with the planner directly in periodic meetings.

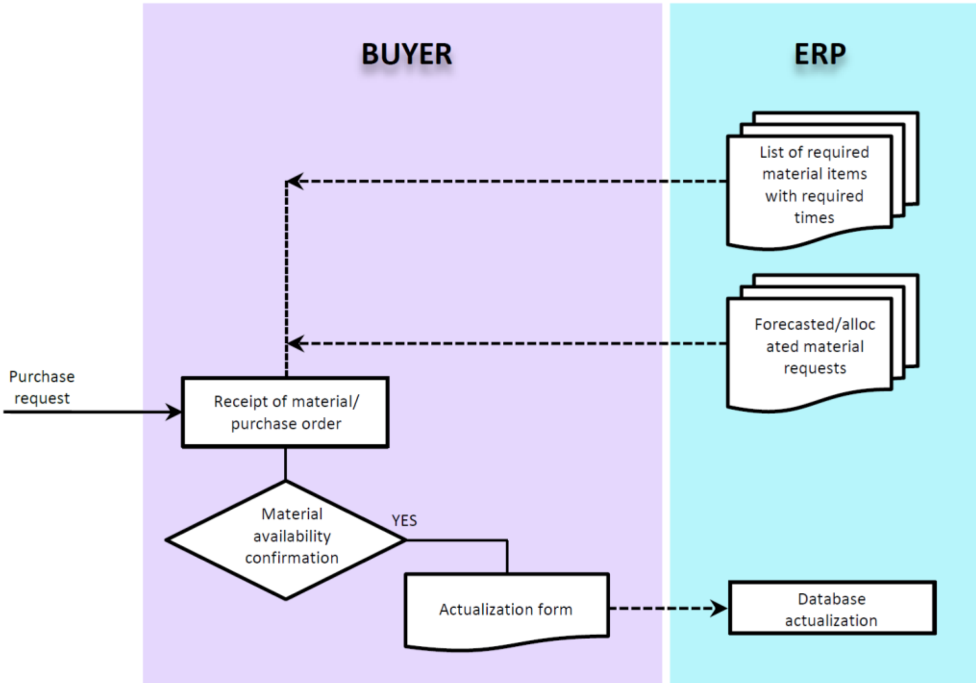


Figure 19 – Current Buyer Workflow (own processing)

Tool shop manager

In general, the tool shop manager coordinates any processes related to the tool shop. In terms of the planning process, he transmits information about the tool shop capacity availability, machine performance and he transmits requirements on the tool material, spare parts and hand tools purchase. His preformation is managed in the same manner as the buyer's – he used the ERP to get a global overview of the tool requirements. All the operational activities are consulted with the planner directly in periodic meetings.

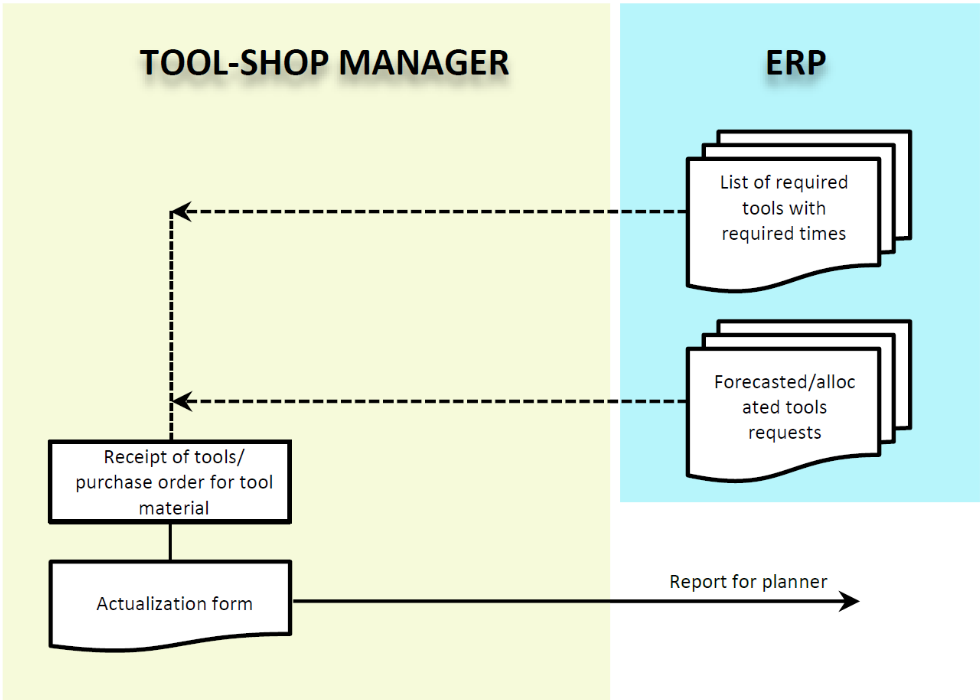


Figure 20 – Current Tool Shop Manager Workflow (own processing)

Forge shop manger

The forge shop manager is responsible for any processes performed in the forge shop. He represents a link between the forge shop and the company management. The forge shop manager informs the management about all the issues that are occurring in the forge shop, such as machine performance and failures, disciplinary problems and the possible need to recruit new employees, he also transmits requests for purchase of spare parts and hand tools, consequently the other operational material. His involvement in the planning process is to provide relevant information to the planner – mainly information concerning human and machine capacity. This is mainly reported during the periodic meetings. The other responsibility of the forge shop manager is to ensure proper production reporting.

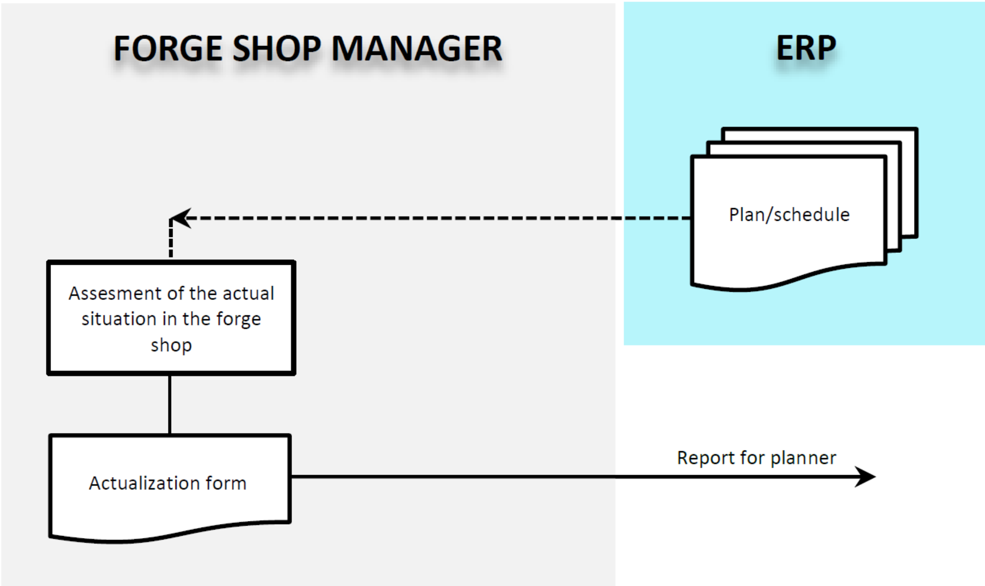
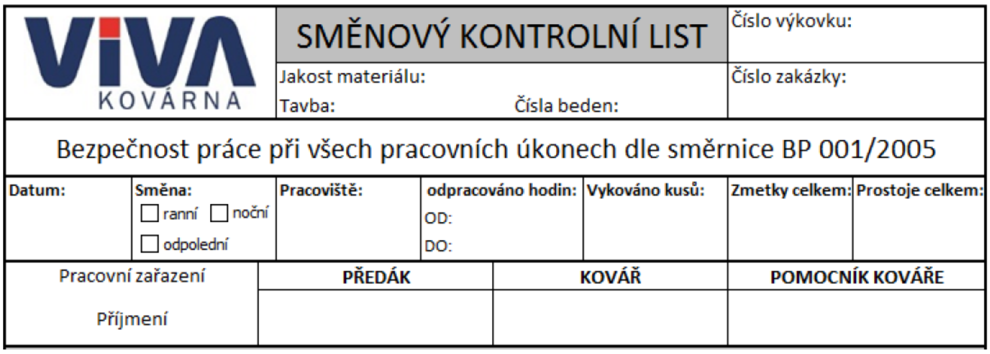


Figure 21 Current Forge Shop Manager Workflow (own processing)

Production Reporting

The process of production reporting is performed by a member of each production line crew. The documentation necessary for the production reporting consists of the production order and shift list.

The shift list is a printed document containing records of each shift. These records are registered in several sections, for the purpose of the production reporting the first section is important with the information concerning the article and order number, crew composition batch size, material quality, melt, start and end of the shift, forgings and scrap amount.


SMĚNOVÝ KONTROLNÍ LIST

Číslo výkovku:

Jakost materiálu:

Tavba: Čísla beden:

Číslo zakázky:

Bezpečnost práce při všech pracovních úkonech dle směrnice BP 001/2005

Datum:	Směna: ranní / noční / odpolední	Pracoviště:	odpracováno hodin: OD: DO:	Vykováno kusů:	Zmetky celkem:	Prostoje celkem:

Pracovní zařazení	PŘEDÁK	KOVÁŘ	POMOCNÍK KOVÁŘE
Příjmení			

Figure 22 – Shift List Snippet (own processing)

The output of the planning process as well as the initiator for the execution of the particular production phase is the production order. The production orders are threefold:

- “D” production order – for the material division process
- “K” production order – for the forging process

- "VR" production order – for the finishing operations executed after the forging process

Each of these production orders is attached in the appendicies.

The production orders have their specific requisites. In general, each production order have its number and barcode for production reporting. Hereafter, it contains information about the beginning and the end of the process and provides information about the quantity of the product. In the next section, there is a list of particular subprocesses and their specifics (e.g. set up time, cycle time, etc.) Each of the subprocesses has its own barcode for production reporting.

Once the requirement of the production order is fulfilled, the production is reported by scanning the barcode, thereafter the next process can be executed. With scanning the barcode and production reporting the data in ERP are updated.

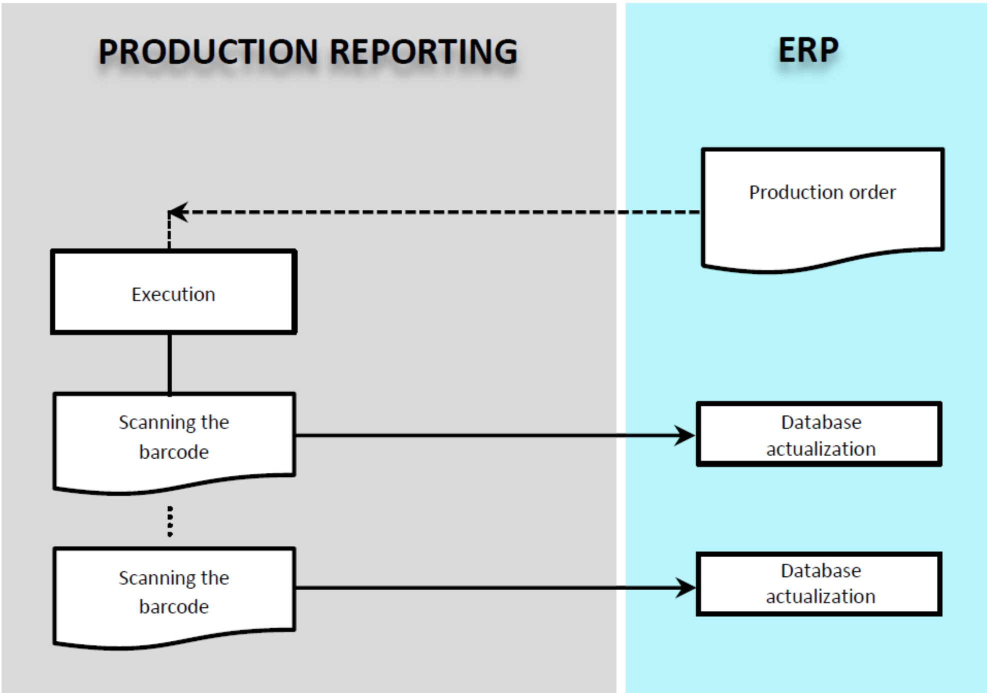


Figure 23 – Production Reporting Process (own processing)

"D" Production Order

This production order serves for monitoring and reporting the production of division processes. The designation "D" corresponds to "dělení" – the division process. This production order is issued after the forging schedule is set. The condition for "D" production order issuing is availability of the material in the warehouse. Once the process defined by this order is finished and reported, the "K" production order can be issued.

"K" Production Order

The "K" production order is the essential document for the forging process ("K" corresponds to "kování" – forging). The processes included in this production order are following:

- Forging process
- Interoperation inspection

"VR" Production Order

The production monitoring and reporting with this production order is a quite problematic and challenging process due to complexity of this order. In the contrast to the previous two document, the VR order contains a wider sequence of processes, each process is represented with barcode. The process cannot be executed until the previous one is reported. This leads to unpredictable downtimes in production reporting, therefore, the data in ERP are not actual, until the VR order is reported as a whole.

Table 1 – Sequence of Order Processing Activities (own processing)

Activity No.	Activity	Manager	Input	Input medium	Output	Output medium
1.	Order receipt	Dispatcher	Customer order	e-mail	Record in ERP	ERP
2.	Assessemet of the Bill-of-material	Planner	List of available BOMs	ERP	Assigned BOM to the article	ERP
3.	Capacity and resource actualization	Planner	Information from the forge shop manager	meeting	Modified machine card	ERP
4.	Modification of the machine schedule	Planner	Infromation from the tool shop manager	ERP	Actual machine schedule	ERP
5.	Issuing of the "D" and "K" production order	Planner	Actual machine schedule	ERP	"D" and "K" production order	Printed document
6.	Production reporting	Machine operator	Finished production process	Barcode scanner	Database actualization	ERP

The table shows particular activities related to the order processing. The big issue is the need of periodical meetings in order to discuss any tool shop and forge shop related conditions, especially the capacity and resource accessibility.

The optimization effort within the order processing is to eliminate such a lack of automatic data transferring and processing.

4.4 Analysis Conclusions

For the purpose of the analysis conclusion, the SWOT analysis is introduced.

STRENGHTS	Weight	Points	Score	Order	WEAKNESSES	Weight	Points	Score	Order
Flexible ERP	0,25	1	0,25	2	User experience needed	0,25	3	0,75	5
Possibilty to insert own algorithms	0,18	1	0,18	1	Planning provides limited flexibility	0,10	2	0,2	3
Actual Database	0,20	2	0,40	3	Impossibility to define specific requirements	0,10	1	0,1	1
Simple work with the data (export to MS Excel)	0,15	3	0,45	4	Impossibility to create multiple variants	0,15	1	0,15	2
Defining user authorization	0,10	4	0,40	3	Impossibilty of cost evaluation	0,20	2	0,4	4
Option to return to the original solution	0,05	5	0,25	3	Planning does not use all the available data	0,20	2	0,4	4
OPPORTUNITIES	**Weight**	**Points**	**Score**	**Order**	**THREATS**	**Weight**	**Points**	**Score**	**Order**
Elimination of the redundant human resources	0,20	5	1,00	5	Planning errors	0,25	2	0,50	4
Monitoring the usage status of tools, line capacity and operators	0,25	1	0,25	2	ERP user retraining	0,15	4	0,60	5
Ability to create and compare multiple variants	0,15	1	0,15	1	Debugging (long term)	0,15	2	0,30	2
The first step to JIT production	0,20	2	0,40	4	Experienced programmer needed	0,10	5	0,50	4
Support for KANBAN implemetation	0,15	2	0,30	3	Possible inefficiency of the proposed solutions	0,20	1	0,20	1
Usability across all the company processes	0,05	3	0,15	1	Cooperation fails among the employees	0,15	3	0,45	3

Figure 24 – SWOT Analysis of the Project (own processing)

The advantage of utilized ERP abas is high level of customization possibilities. Analysis has shown, the ERP has high potential, however the habitual approach of data sharing and processing does not support extensive abas utilization. The users have incomplete knowledge of the abas functionality, therefore they are inertly tending to leave out the abas possibilities.

The current approach of planning and scheduling suffers from the well-timed data absence due to traditional long-term ways of data transmitting. The characteristic sigh of such arrangement leads to frequent unrecognized collisions in the resources assignments. At the moment of order receipt, the dispatcher does not make any effort to check the constrain limits for fulfilling the order. The common strategy is to accept all the orders and to utilize the planning model based on unnecessarily long time reserves. Moreover, this approach leads to inefficient production capacities utilization. The lack of exact in-time data is compensated by systematic underestimating of own possibilities.

The abas is suitable and powerful tool for gathering, managing and distributing information related to the planning and scheduling process, however it is necessary to propose more effective planning concept and then to systematically train the users in order to improve their knowledge of abas functionality and to enlarge their competencies.

The most elementary threat of each complex project is the underestimation or insufficient comprehension of some system aspects to which the project is dedicated. The negative impact of shortcomings and errors in the project lead to development prolongation and cost increase. It is necessary to repair all the faulty project elements which should have been solved in previous stages. The most critical scenario is the necessity to redefine project objectives and to undergo extensive modifications in the stage at which the project is almost completed and trial operation has started. This risk is possible to be reduced by thorough project discussion with all interested sides, eventually with the independent experts. Such a procedure leads to continuous shortcomings elimination and to minimization of repairs within the final stage.

5 PROJECT DEFINITION

This chapter contains general information of the project. The principle objective is formulated in the logical framework. Besides the list of particular objectives, this document contains a list of project risks that may occur during the project. This risk formulation is essential for following risk analysis – RIPRAN (Risk Project Analysis). The last document of the project definition is the project schedule.

5.1 Logical Framework

At the stage of project definition and preparation, the logical framework is made. This document in simple way displays the particular project activities and outputs needed to meet particular objectives on the one side, particular inputs and verifiable indicators on the other.

Project Description	Verifiable Indicators	Sources of Verification	Risks
Principle Objective Rationalization of the production process scheduling - Forging	Increase of the planning efficiency (required time and human resources for the planning process)	Diary method	1. Incompatibility with another version of the existing ERP, respectively with Windows.
Specific Objectives			
1 Formulation of the requirements for modified planning and scheduling system	The ability to include such conditions, that are not allowed in commonly used algorithms	Approval with countersignautre	2. Change of the ERP solution
2 Design and implementation of the database containing input and output data for planning algorithm	The database should contain such data that make possible to register the wear of tools, the utilization of production lines and their operators. There should be a possibilty of cost evaluation of the individual planning and scheduling variants.	Database approval	3. Unwillingness of employees to cooperate
3 Desing and implementation of the planning algorithm to corporate ERP	Test version	ABAS	4. The proposed solution will not coincide with the planning and scheduling of the entire process
4 Proposed solution debugging	There is a noticable difference between current and modified planning and scheduling method proved with the ecomic benefits.	Test version in ABAS	5. The specifics of the proposed solutions prove to be unnecessary
Outputs			
1.1 Defined requirements for the modified planning and scheduling system	List of requirements		
1.2 Database of input and output data for planning and scheduling system	Database		
1.3 The planning and scheduling algorithm in ERP	Algorithm in ABAS		
1.4 Debugged and functional solution	Final version of the planning platform in ABAS		
Activities	**Inputs and Resources**	**Activities Timeframe**	
1.1.1 Gathering information from employees	Interview	1 month	*09/2015*
1.1.2 Analysis of data from ERP system	Data analysis in MS Excel	1 month	*10/2015*
1.1.3 Discussion on system requirements	Interview/brainstorming	1 month	*11/2015*
1.1.4 Formulation of system requirements	Interview/brainstorming	1 month	*12/2015*
1.2.1 Database design	MS Excel	2 weeks	*01/2016*
1.2.2 Database implementation to ERP system	ERP ABAS, SQL (Structured Query Language), MS Access	3 weeks	*02/2016*
1.3.1 Agorithm design	C#, ABAS	1 month	*03/2016*
1.3.2 Algorithm implementation	C#, ABAS	4 months	*04/2016-07/2016*
1.4.1 Testing and debugging	ABAS	2 months (1 month at least)	*08/2016-09/2016*
1.4.2 Project evaluation		1 week	*09/2016*

Figure 25 – Logical Framework (own processing)

5.2 Project Schedule

The duration of the project is illustrated by the project schedule. This simple diagram is a quite good visualization tool from which it is easy to determine the current stage of the project and how much time is left before its completion.

The project was launched in September 2015. The initial phase was to collect information from employees followed by the ERP data analysis. During November and December 2015, several discussions over the requirement of the planning system were initiated, subsequently the results were formulated. Since January 2016, the process of database design started, thereafter the improved database was imported into the ERP and the algorithm design could be initiated. The implementation of the algorithm into the ERP is very challenging and time consuming activity which is stated to last four months at least. If the implementation is successful, the two months process of testing and debugging should start. The project is meant to be completed in September 2016.

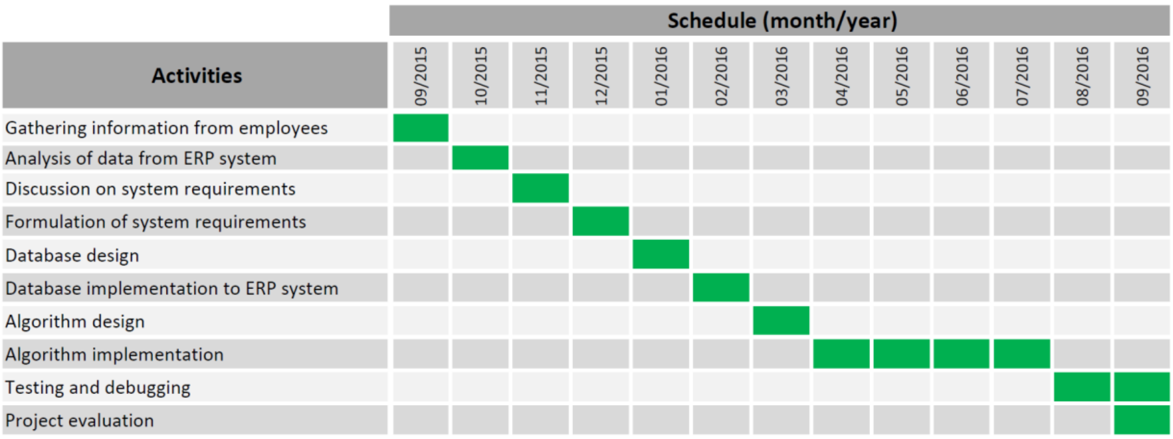


Figure 26 – Project Schedule (own processing)

5.3 Risk Analysis

In the preparation stage of the project, it is necessary to process the risk analysis in order to define and evaluate potential risks that may affect the project progress.

In the first step, particular threats are formulated and complemented by possible scenarios. Thereafter, the probability of the threat occurrence and impact on the project are assigned. After that, the risk value is calculated. This information is included in *Table 2*.

Table 2 – RIPRAN 1 (own processing)

Risk No.	Threat	Scenario	Note	Probability	Impact on the Project	Risk Value
1.	**Incompatibility with another version of the existing ERP, respectively with Windows**	Extension of the project duration, cost increase	The need to modify the proposed solution to be compatible.	**LP** - Low Probability	**MNI** - Medium Negative Impact	**HRV** - High Risk Value
2.	**Change of the ERP solution**	Extension of the project duration, cost increase	Possibility that the proposed solution will not be implementable in other ERP, therefore it is necessary to "repeat" the project for new ERP system.	**MP** - Medium Probability	**MNI** - Medium Negative Impact	**MRV** - Medium Risk Value
3.	**Unwillingness of employees to cooperate**	The negative attitude to change long-used planning method	The proposed planning and scheduling method will be quite different from the present, therefore the employees need to be retrained.	**HP** - High Probability	**SNI** - Small Negative Impact	**MRV** - Medium Risk Value
4.	**The proposed solution will not coincide with the planning and scheduling of the entire process**	Reprocessing of project output, extension of the project duration, cost increase	Proposed planning and scheduling algorithm takes into account forging process only and ignores other processes.	**MP** - Medium Probability	**GNI** - Great Negative Impact	**HRV** - High Risk Value
5.	**The specifics of the proposed solutions prove to be unnecessary**	Possible project termination	Possible irrelevance of proposed solution specifics.	**MP** - Medium Probability	**GNI** - Great Negative Impact	**HRV** - High Risk Value

Table 3 contains recommendations for mentioned threats elimination and therefore the reduced risk value of each threat.

Table 3 – RIPRAN 2 (own processing)

Risk No.	Threat	Recommendations	Reduced risk value
1.	**Incompatibility with another version of the existing ERP, respectively with Windows**	When programming, use such source codes and settings so the algorithm can be implemented into commonly used ERP, respectively into Win 7, 8, 10.	**MRV** - Despite of the measures it is possible the proposed solution will not be compatible with other operation systems.
2.	**Change of the ERP solution**	Set the condition, the company should not switch to another ERP throughout the project duration.	**No risk anymore.**
3.	**Unwillingness of employees to cooperate**	Involve the key employees and users of ERP in the project and thus motivate them to cooperate.	**LRV -** Persisting possibilty of the negative attitude of some employees, however the impact on the project is reduced.
4.	**The proposed solution will not coincide with the planning and scheduling of the entire process**	Set out the time period for debugging the proposed solution and its possible modifications as part of the project.	**MRV** - The measure will reduce the probability of the risk.
5.	**The specifics of the proposed solutions prove to be unnecessary**	Before starting the project, consult with key employees and users which specific functions should have the proposed solution.	**MRV** - Reduce of the threat probability.

Through the risk analysis, the probability of risks occurrence was significantly eliminated. The risk of changing the ERP solution was absolutely suppressed. The other risks were eliminated on medium risk values that are acceptable.

6 OPTIMIZATION PROPOSAL

The shortcomings described in the conclusion of the analytical part are possible to be partly eliminated by introducing more sophisticated planning system, which will be gradually implemented into the current ERP – abas.

The proposed planning system further specifies the processes carried out by each ERP user. For this purpose, the database system is meant to be extended consequently with designing a model including the material preparation, the material division and forging. This system generates the material purchase orders with their delivery times confirmed by a buyer. The production planning and a tool preparation is based on the same principle. The other "after forging" operations are not inspected so far since these processes represent a secondary operational problem. In this phase of an algorithm development, secondary problems are not to be considered. The proposed planning and scheduling system is based on customer order processing.

The users of the modified systems are characterized with the original roles within particular departments – dispatcher, buyer, planner, tool shop manager, forge shop manager. However, the functionality is ensured with formally defined information flows. Such a solution enables to overcome some of the serious shortcomings of the current method of production planning and scheduling.

Planning based on Choice of Proposed Alternatives

The proposed planning algorithm does not apply any of the common methods of exact auto-optimization (such as the simplex method), but it enables the creation of dynamic scheduling alternatives with options of continuous modification according to the unforeseen circumstances. For the purpose of the alternative choice, the system provides the cost evaluation of each alternative using hour rates of operators and machine tariffs. This cost is not the accounting cost but the cost influenced by the alternative choice.

Process of Order Acceptance

Within the proposed system, the dispatch does not accept the customer order unconditionally. The order acceptance is based on realistic assessment of "capacity" options automatically evaluated and processed into the form of preliminary planning alternatives. Therefore, the dispatcher is able to negotiate realistic delivery time for the order. The order acceptance initiates the requirement for the planner to compile a definite production schedule afterwards. Yet at the stage of customer order confirmation – order acceptance, the system books the required resources, therefore no uncontrolled “stealing” occurs.

Time Reserves reducing

The detailed production order scheduling is subjected to planner’s processing. The planner does not have to work with the heuristic time reserves, but he relies on an accurate description of resources availability.

The effect of the planning risks was previously included into the aggregate time reserves. The intention of the optimization is to maintain this concept, however with the purpose to separate the exact technological data from the reserves expertly set by the planner in the greatest possible extent. Allocation and utilization of the reserve in the planning process depend on the time perspective, the uncertainty increases with the time perspective prolongation. The information on the resources availability is continuously updated by the buyer, tool shop and forge shop managers. These users in their work follow the requirements automatically generated by the system which registers the accepted order and the level of work-in-progress.

6.1 Particular Processes of Proposed Solution

The proposed planning and scheduling system keeps the original assignment of particular processes to the specified group of ERP users:

- Dispatcher
- Buyer
- Tool shop manager
- Planner
- Forge shop manager

In terms of the planning and scheduling process, particular roles of the ERP users were slightly redefined. Their modified responsibilities involve greater ERP usage. They have to assess the ERP reports as well as to update database with the relevant data in their scope. Such a decentralized ERP accessing enables to accelerate information flows and increase the data reliability avoiding the face-to-face communication which is sometimes error prone.

6.1.1 Dispatcher Activities

The key role of a dispatcher is to communicate with customers, usually one dispatcher is assigned to specified group of customers. In general, the dispatcher should secure the database is updated to reflect actual information about the customer performance. Concerning these specified roles, the dispatcher makes two types of decisions:

- The processing and conditioned acceptance of the preliminary order
- The processing and conditioned acceptance of the forecast

6.1.1.1 Customer Order Processing

The dispatcher's decision about the order acceptance depends on execution of following activities:

1. Formalization of the preliminary order.
2. Check the ERP output – weather the article is in database already, weather the customer order is in accordance with the forecast. In case the article is not in the database, the dispatcher obtains a report and then he refuses the order. In that case, the dispatcher should consult this situation with particular department. When no collision occurs, the ERP check the material availability and generates the preliminary purchase order if necessary. Consequently, the ERP takes into account the material availability time, creates the preliminary order and builds up the planning alternatives automatically; the ERP takes into account the estimated maximum time reserve. Finally, the ERP provides a report containing the list of planning alternatives (the alternative's multiplicity is given by the possibility of production on different production lines) – the essential information in the planning alternative is the possible date of production order finalization.
3. Informing the customer about the planning results, after consultation with the customer the dispatcher accepts or refuses the preliminary order. In case of preliminary order acceptance, the ERP sets this order into planning queue for later processing by the planner, therefore the ERP allocates the required resources.

6.1.1.2 Customer Forecast Processing

The forecast is processed in the same manner as the order, however no planning alternatives are built up. Only the tool material purchase order is created in case of forecast acceptance.

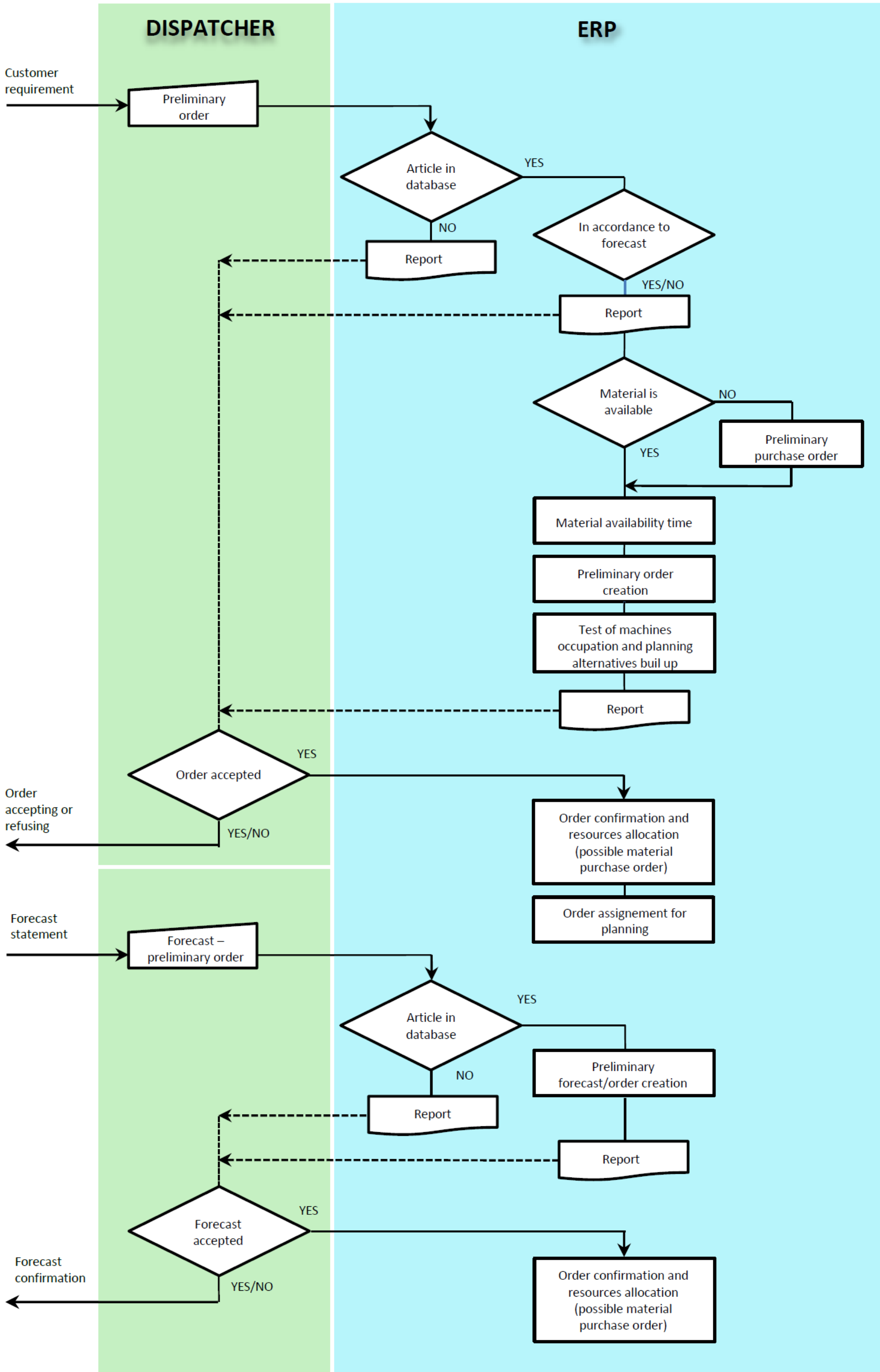


Figure 27 – Proposed Dispatcher Workflow (own processing)

6.1.2 Buyer Activities

The buyer's responsibility is to ensure the availability of a material. He has to follow the outputs provided by ERP, these outputs are as follows:

- List of required material items with required times
- Forecasted or allocated material requests

The assessment of mentioned lists is managed in accordance with the prior production of particular articles.

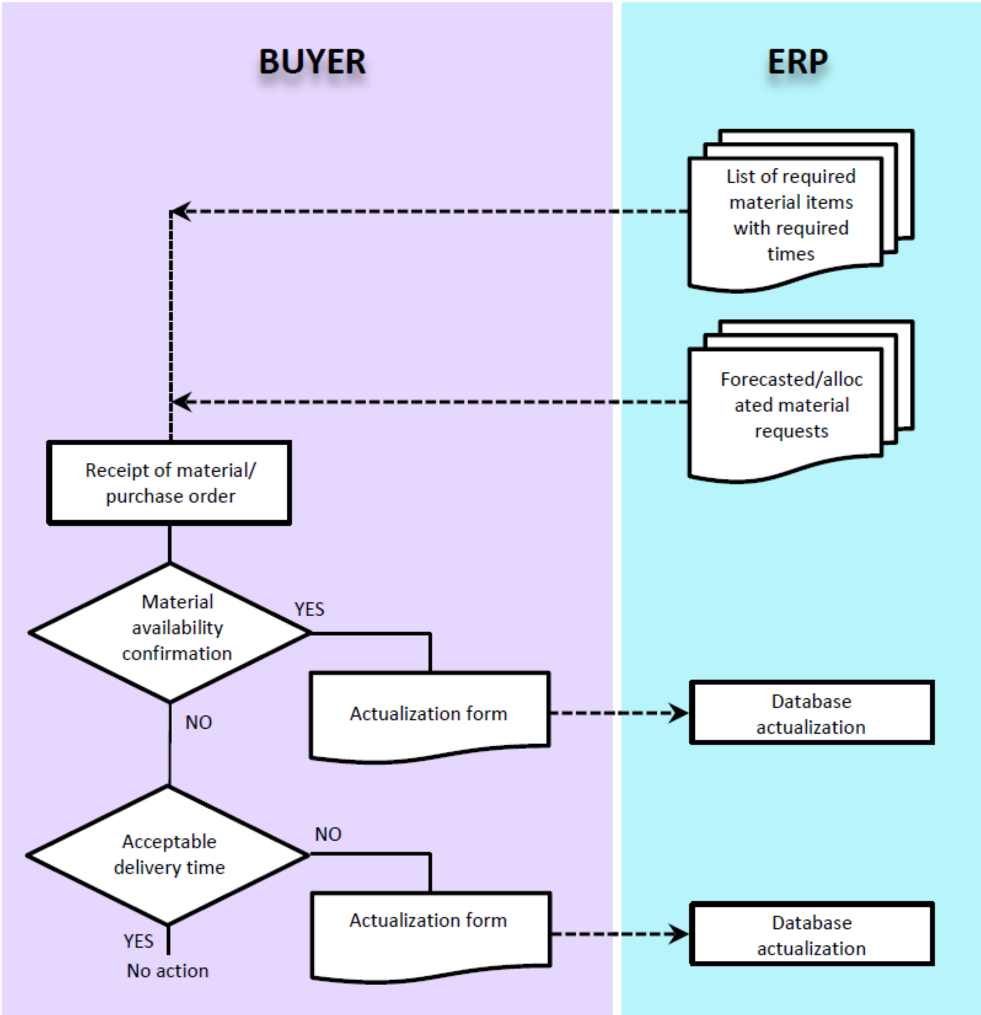


Figure 28 – Proposed Buyer Workflow (own processing)

List of required material items with required times

The material mentioned in this list is strictly required in order of the planned production processes.

Forecasted or allocated material requests

The material is demanded due to the accepted orders and forecasted orders. The delivery times are predicted by expert estimation of the planner.

The buyer has to assess these requests in accordance of the vendor's possibilities, therefore he purchases the material. The process of purchasing is divided into two phases:

- The vendor confirms the delivery of a material
- The receipt of the material

During both of these phases, the buyer has to update the database to ensure the best possible knowledge of delivery times of material. In some cases, there are occasions when the material cannot be delivered in promised time. This situation is essential for the planner.

6.1.3 Tool-shop Manager Activities

Besides of other activities belonging to his position, the tool shop manager ensures any tools (forging dies) needed for the production. Concerning the information flow, the activities this manager are similar to the buyer's activities. The tool shop manager has to assess the output reports from ERP:

- List of required tools with required times
- Forecasted or allocated tools requests

The assessment of mentioned reports is managed in accordance with the prior production of particular articles. The essential role plays the production schedule. During the process of tool preparation, the tool shop manager has to update the database with relevant data.

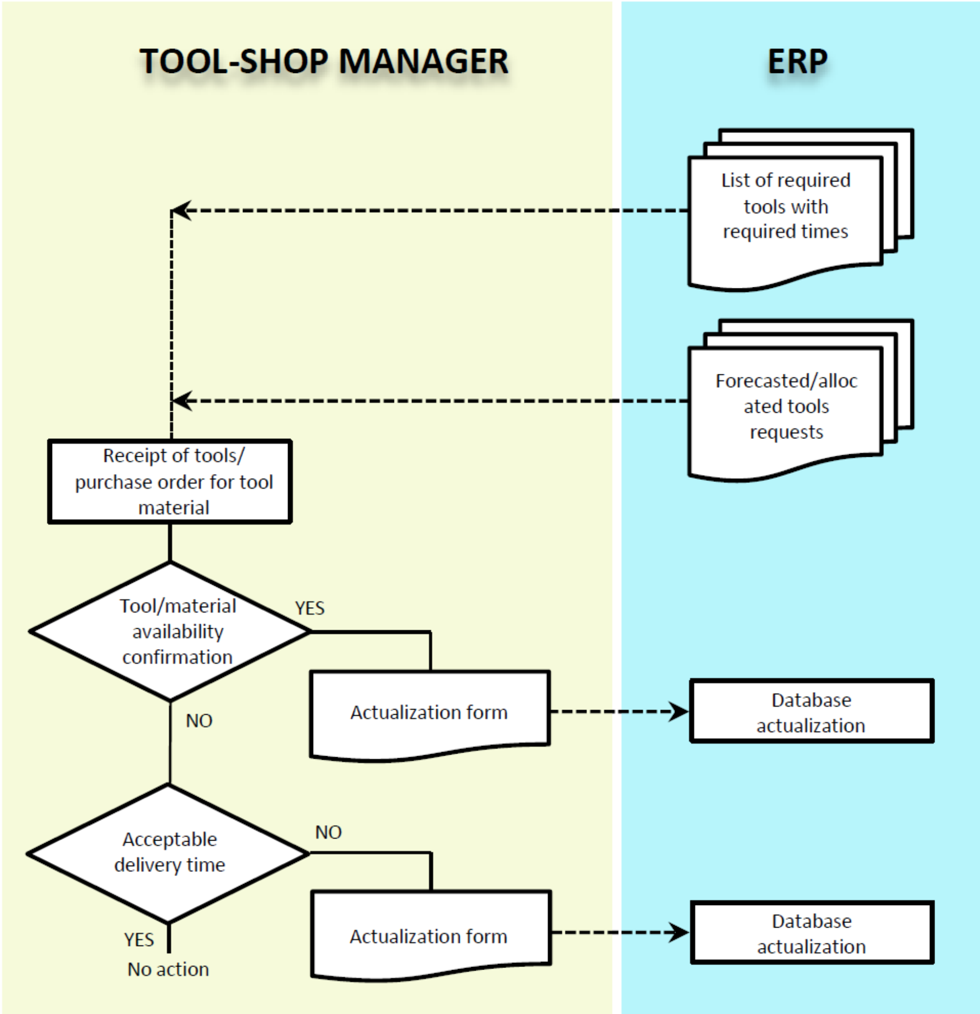


Figure 29 – Proposed Tool-Shop Manager Workflow (own processing)

6.1.4 Planner Activities

In contrast with actual planner activities, the proposed solution reduces necessity of face-to-face communication at minimum. The planner in proposed model works with more formalized data. The level of planner's knowledge and experience can be quite lower since many of the qualified estimates are included in ERP database. The ERP is able to prepare list of planning alternatives, the startup time of production is set in the earliest possible time. The planner can modify the alternatives in order to reach an optimal schedule. Therefore, he takes into account several not strictly prescribed conditions, e.g. customer priority, order priority, maintenance, training etc. The operational alternative is a result of setting following parameters:

- Choice of bill-of-material
- Set of batch size

- Set the startup time
- Reserve time reduction/enlargement
- Crew modification

The important advantage of processing of planning alternatives is the possibility of time reserve modification. The standard scenario provides greater time reserve for far future, in close forecast this time gap can be significantly reduced. The functionality of ERP provides automatic checking of each modified parameter.

The planning process for ordered article/articles is completed by choosing the one of proposed alternatives. Even the chosen alternative may be modified in the next planning step except the production processes which have started already.

The order processed by the dispatcher enters the ERP, consequently the order items are automatically analyzed. Based on the technological data the appropriate set of production batches is created. These batches are saved preliminary only in order to enable further processing. The process of batch creating and ordering is a quite complex task and requires well-structured relational database.

The detailed process description the matter of software implementation provided by the external specialist provided by the ERP vendor.

Nevertheless, the planning process analysis leads to preliminary proposal of the database tables, their fields and the relations among the tables. The database proposal is described in the following chapter. The database proposal is meant to be a part of software modification request and it is supposed to be precisely discussed with the company representative and the programmer.

The planner investigates the preliminary set of batches in order to start the planning procedure. Then he makes decisions periodically whether to create, modify or delete planning alternative. This step is to be repeated until the final set of alternatives is ready for the comparison. The alternative creations and deletions are simple operations. During the alternative modification, the planner realizes the steps described in the flow diagram. His performance is controlled by the ERP and each planner's entry is immediately checked. After the alternatives comparison, the planner chooses one of them and states several batches (from the beginning of the planning alternative) valid. These valid batches are excluded from the cyclical process of alternative creation.

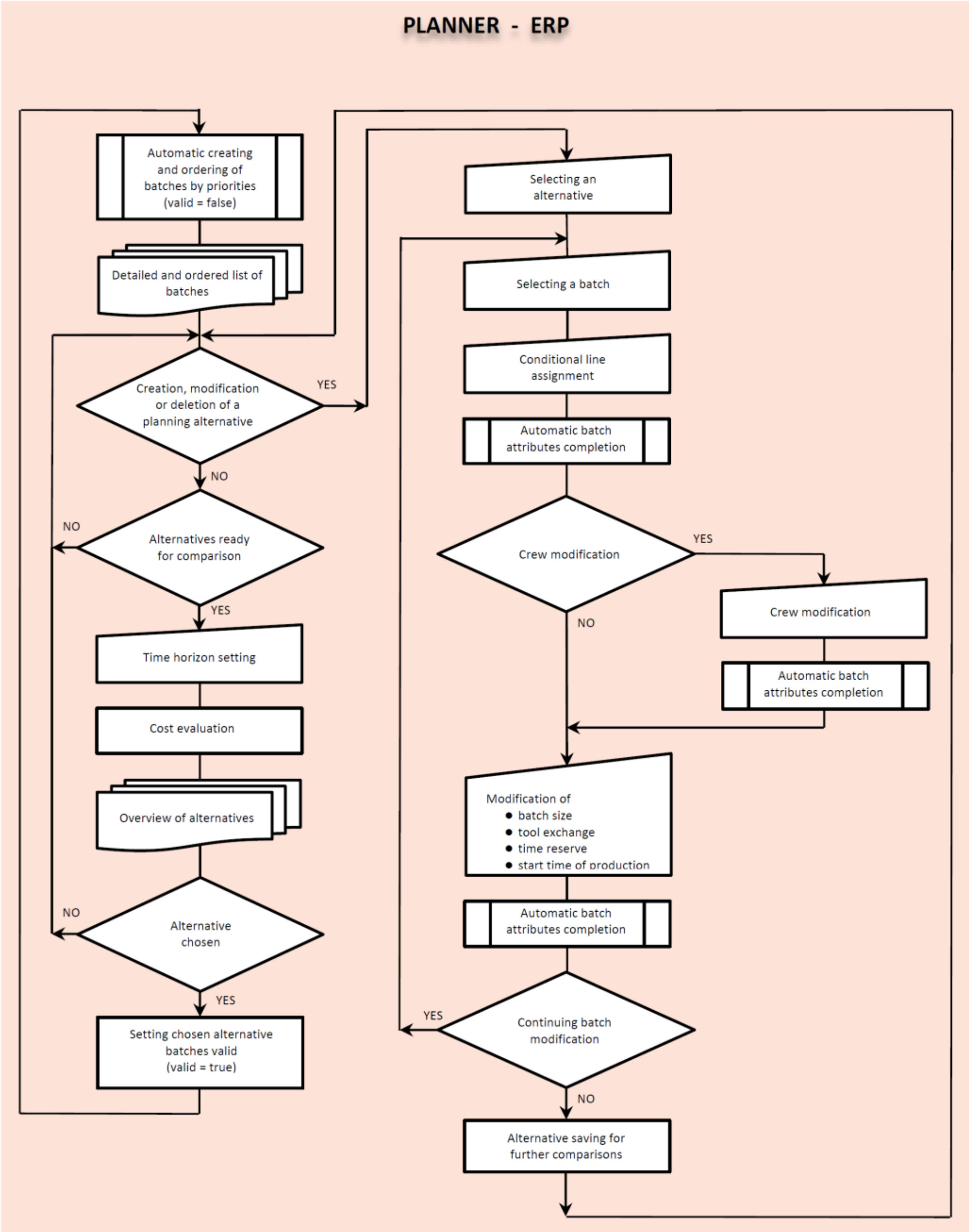


Figure 30 – Proposed Planner Workflow (own processing)

6.1.5 Forge-shop Manager Activities

The forge shop manager is responsible for the production processes realized in forge shop. He ensures the database updating in accordance with actual situation in forge shop:

- Machine breakdowns
- Organizational problems (e.g. missing tool or material)
- Human resources irregularities (injuries, illness, qualifications etc.)

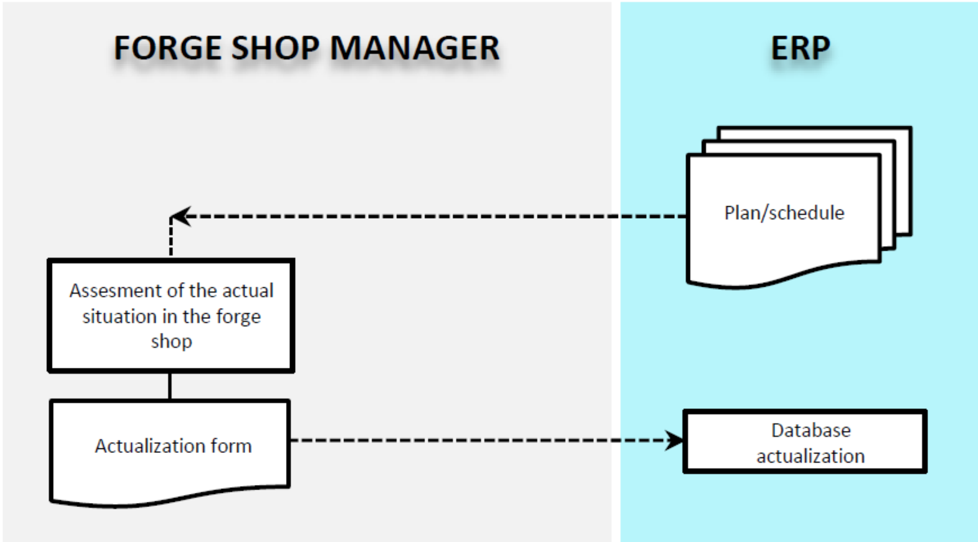


Figure 31 – Proposed Forge Shop Manager Workflow (own processing)

The process of production reporting is taken from the existing model.

6.2 Database Design

The essential component of the proposed solution is the system of database tables. These tables represent precisely formalized information supporting the planning and scheduling process as well as the production reporting. The database tables contain detailed structured data and their interrelations. For a purpose of better visualization, the database tables are divided into four sections:

- Input tables
- Prescribed tables
- Dynamic tables
- Output tables

The affiliation of particular tables to a section is not set strictly, it only represents the typical position in the database; e.g. the prescribed tables can be modified during any process by adding or modifying the *bill_of_material* etc.

The left section of each database print screen represents a map of relations among tables. The right section contains a list of tables with their fields. The type of field data is described by the unit column. All the IDs are integer numbers being unique in the table where it is used as a key. The key IDs are printed bold.

6.2.1 Input Tables

The following print screen of input tables represents the input information related to customer order.

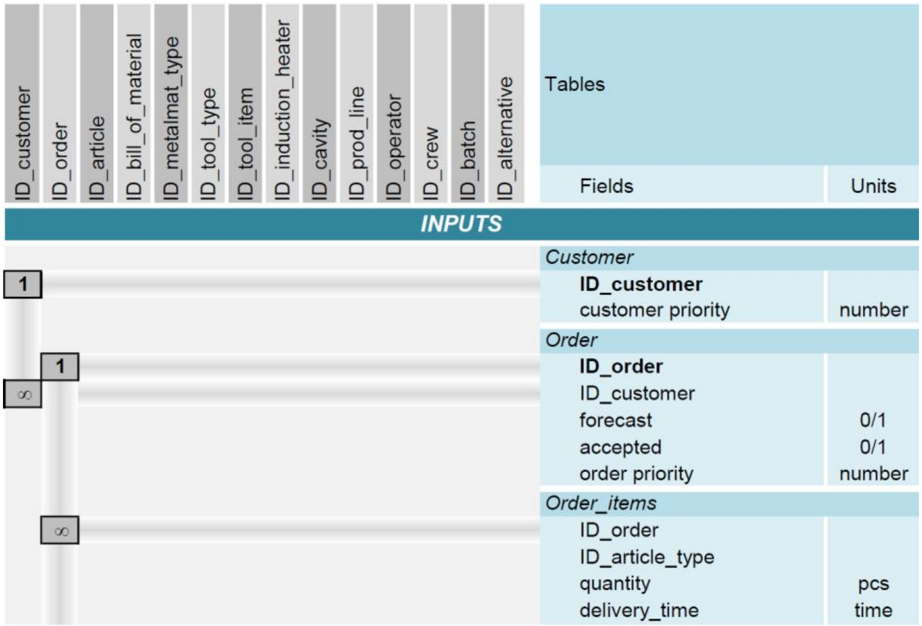


Figure 32 – Input Tables (own processing)

Customer

The customer table besides the key *ID_customer* contains basic *customer priority* characteristic needed for the planning alternative assessment. The *ID_customer* identifies a customer and it refers to other tables included in the system. The *customer priority* characterizes customer creditworthiness or importance in the planning process. Each customer has assigned a number ranging from 1 to 10, where 1 represents the highest priority and 10 referred to the lowest priority. Actually, the customer relating information is more comprehensive, it must hold name, address, identification number of organization (IČO) and many other important data yet not relevant for the planning process.

The customer table could be perceived as a prescribed one due to relative stability of customer set. However, the table is positioned in the input section to emphasize the possibility of being enlarged by a dispatcher.

Order

The order table represents each customer order. This table originates as a conditional entity and it actually enters the database in the moment when the order is stated as accepted.

The key field is the *ID_order*. The customer requesting the order is referred in the field *ID_customer*. The *order_priority* is used in the same manner as the customer priority. The field *forecast* indicates whether the order is to be processed as a forecast (1 – true) or not (0 – false). The field *accepted* is essential for proposed planning system. The field *accepted* is taken into account just for the orders (not forecasts). At the beginning, it is set to 0 (false), while the order is strictly set (it is placed into a schedule by planner) the value is turned to 1 (true).

Order_items

Each order consists of requirements for distinguished article amounts. The particular requirement belonging to a customer is expressed by value of *ID_order*. The field *ID_article_type* determines the type of article (demanded forging product). The amount of demanded product is expressed in the field *quantity*, the agreed delivery time is held by field *delivery_time*.

6.2.2 Prescribed Tables

The tables in this database section are designed in order to reflect production related data. The table are stable relatively, they can be enlarged in rare occasion, e.g. the design department issues new bill of material etc.

Article_type

This table contains all the product types with existing bill of material. The table assigns a product *name* to each *ID_article_type*.

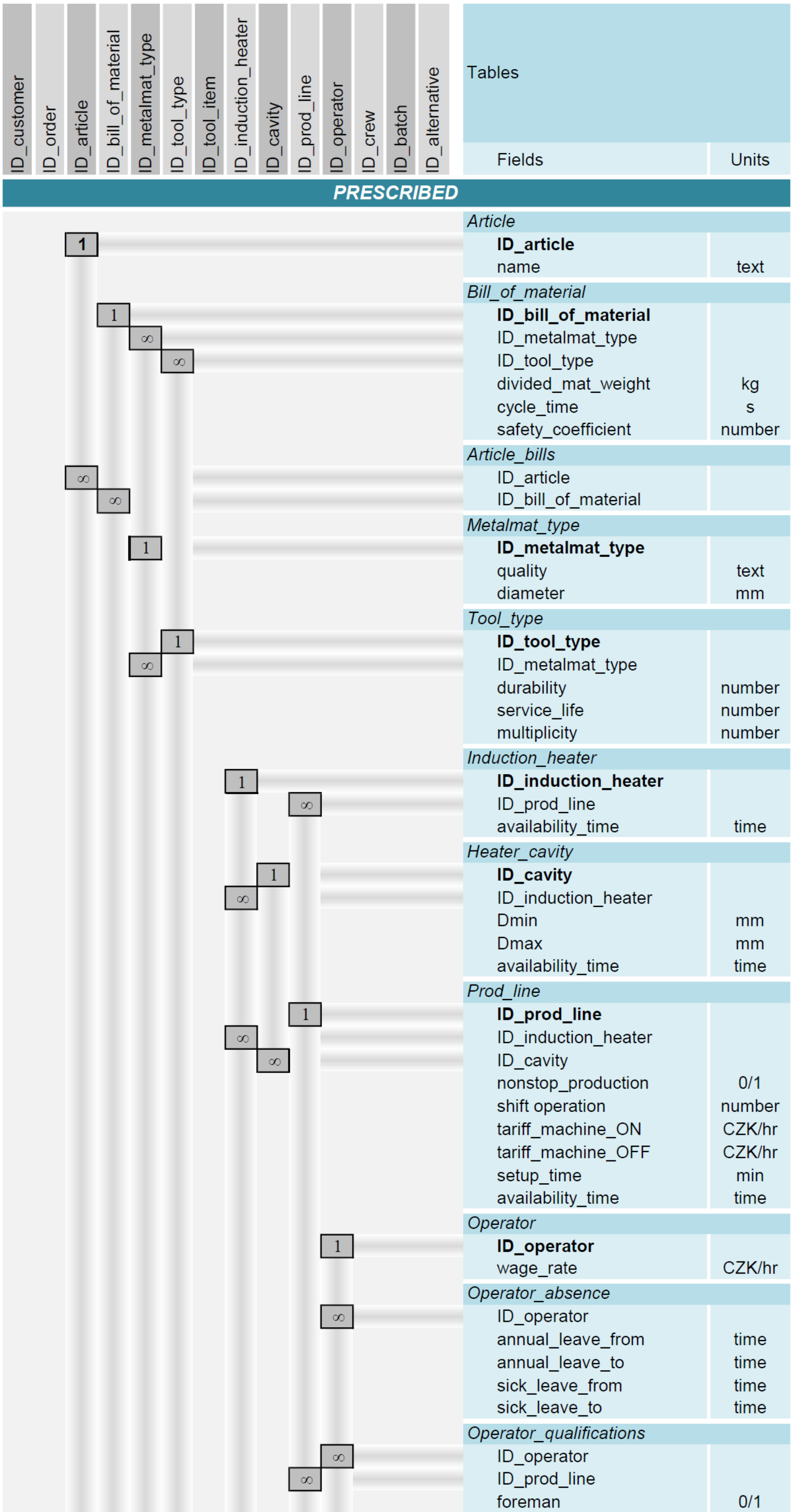


Figure 33 – Prescribed Tables (own processing)

Article_bills

The table is introduced in order to express the fact that each article (defined as *ID_article*) can be manufactured in accordance to one or more bills of material (*ID_bill_of_material*).

Bill_of_material

In general, the bill of material describes all the technological steps needed for product manufacturing. Each of the bill of material is represented by its specific *ID_bill_of_material*. The material needed for the division process is defined by *ID_metalmat_type* and the information about the weight of divided piece of material is expressed by *divided_mat_weight*. The *ID_tool_type* determines a tool type for forging process. Time consumption of the production process (forging) is described by the *cycle_time*. To cover the uncertainty of required production time the *safety_coefficient* is introduced, this field is expressed as a percentage.

The proposed solution contains further data not relevant for the purpose of planning and scheduling.

Metalmat_type

The name of the table is derived from metallurgic material type which is characterized by a *quality* and its *diameter*. The *metalmat_type* represents a commodity purchased from a material supplier. Some of the metallurgic materials are used for forgings production another for tool manufacturing. The key of this table is *ID_metalmat_type*.

Tool_type

This table represents a list of tool types in the database. Particular tool types are assigned to individual *ID_tool_type* key. Each piece of tool is manufactured from a specific material described by the field *ID_metalmat_type*. The type of each tool is characterized by fields: *durability*, *service_life* and *multiplicity*. The durability is the maximum count of ram strokes till it is necessary to renovate a tool of the particular type. Another fundamental *tool_type* characteristic is a service file represented by filed *service_life*. The service life is the maximum count of renovations feasible for the given tool type. The last *tool_type* characteristic is a multiplicity which corresponds to count of forgings processed with one ram stroke.

Induction_heater

All the production lines consist of an induction heater, forging press and cutting press. The induction heater is a device for divided material heating. The table *induction_heater* contains a list of induction heaters. Each heater has its own *ID_induction_heater* and belongs to particular production line (*ID_production_line*). A usage availability of an induction heater is expressed by means of *availability_time*. Once the value is 0, the heater is available. Otherwise, the value means date and time when heater is available.

Heater_cavity

During the heating process, the heating "medium" is a cavity installed on suitable induction heater. The suitability is determined by dimensions of these devices. The table *heater_cavity* contains a list of cavities, the key in the table is *ID_cavity*. The field *ID_induction_heater* corresponds to used induction heater. The size range of heated material is determined with fields *D_min* (minimal diameter) and *D_max* (maximal diameter). The field *availability_time* has the same meaning as the same field in table *induction_heater*.

Prod_line

The table *prod_line* contains relevant data for production line description. The key is *ID_prod_line*. Fields *ID_induciton_heater* and *ID_cavity* represent relation to records in tables *induction_heater* and *heater_cavity*. The *nonstop_prodcution* field corresponds to 24 hours operation. The *shift_operation* field corresponds to number of shifts with values 1, 2, 3 (1 – one shift, 2 – two shifts, 3 – three shifts). The fields *tariff_machine_ON and tariff_machine_OFF* express the hour rates of operating and non-operating machine. A setup time is derived from a standard regulation the set up operations. The value of *setup_time* is expressed in minutes. Finally, the field *availability_time* has the same meaning as in the previous table.

Operator

The crew operating on each production line is composed of three members – operators. The table *operator* contains relevant data for each operator. The key is *ID_operator*. For further cost evaluation, the table introduces the filed *wage_rate*, i.e. the hour rate of each operator.

Operator_absence

An absence is assigned to an operator with *ID_operator*. The operator's utilization of annual leave is characterized by fields *annual_leave_from* and *annual_leave_to*. The operator's sick leave is characterized by fields *sick_leave_from* and *sick_leave_to*.

Operator_qualifications

The operator's ability to operate a set of production lines is characterized by records in table *operator_qualifications*. Each record in the table consists of *ID_operator*, *ID_prod_line* and logical field *foreman*. The *foreman* field acquires value 1 when the operator is able to be a foreman of the production line. Otherwise, the value is set to 0.

6.2.3 Dynamic Tables

The so called dynamic tables represent production resources being dynamically changed during the production process. These tables are related to material and tools.

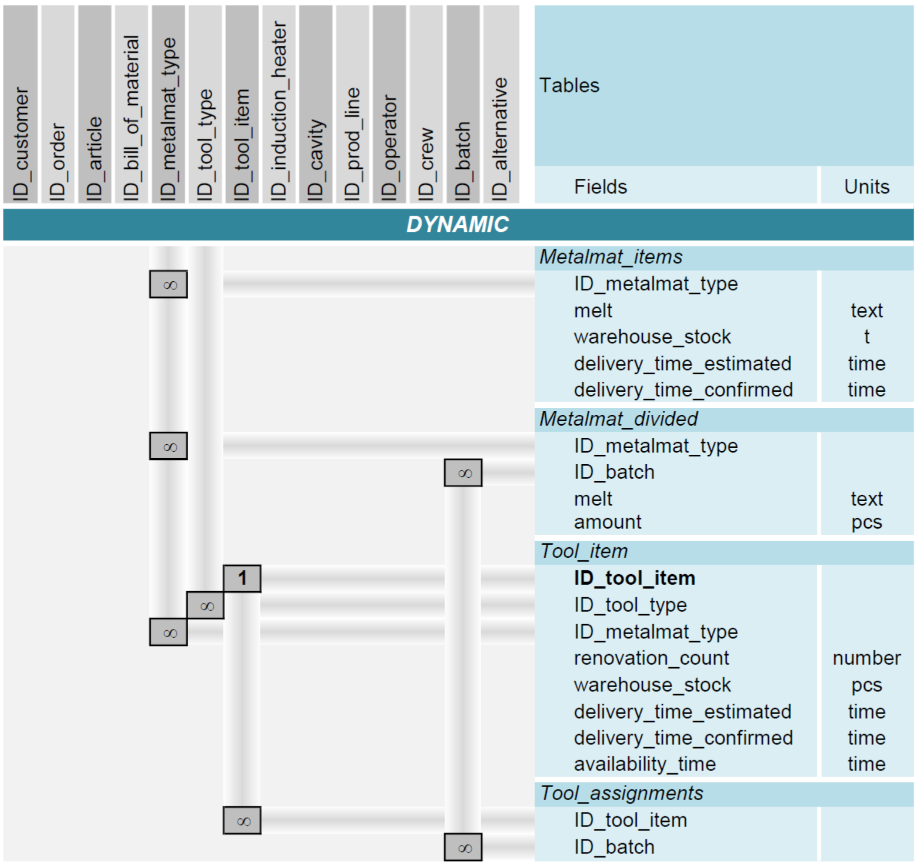


Figure 34 – Dynamic Tables (own processing)

Metalmat_items

The table *metalmat_items* contains records expressing the material stock in warehouse or the requested material. The field *ID_metalmat_type* specifies the material type. The textual field *melt* describes the melt characteristic of particular materials. The amount of material is included in the field *warehouse_stock*. It expresses either the requested material or the material available in stock already. The fields *delivery_time_estimated* and *delivery_time_confirmed* express the appropriate delivery terms of material receipt. The 0 value in these fields has special meaning described in the following table.

Table 4 – Delivery Times of Material (own processing)

Material Disponibility	**Fields**	
	Delivery_time_estimated	*Delivery_time_confirmed*
Material is requested due to the order acceptance by dispatcher. Only in case the material is not available in the warehouse.	Valid value	0
Once the material request is processed by buyer, the new value of delivery time (delivery_time_confirmed) is set or updated.	0	Valid value
Material is available in the warehouse.	0	0

Metalmat_divided

The records in *metalmat_divided* table represent the set of individual batches of divided material. The field *ID_metalmat_type* characterizes the material. The field *melt* is another characteristics of the material. The field *amount* characterizes the number of divided pieces of the material. Each given record belongs to one production batch (field *ID_batch*).

Tool_item

For the purposes of effective usage of tools, the table *tool_item* is introduced. The particular fields contain data to monitor each tool life cycle. The field *ID_tool_item* is the key for this table. The field *ID_tool_type* defines the tool type. The rest of the fields are continuously updated to monitor the tool consumption level. The field *renovation_count* denotes the actual count of renovations of the tool. The tool stock is expressed by field *warehouse_stock*. The field *ID_metalmat_type* corresponds to a material used for tool manufacturing. The time availability of each tool is expressed by field *delivery_time_estimated*, *delivery_time_confirmed* and *availability_time*. The value meaning is described by following table.

Table 5 – Delivery Times of Tool (own processing)

Tool Disponibility	**Fields**		
	Delivery_time_estimated	*Delivery_time_confirmed*	*Availability_time*
Material is requested due to the order acceptance by dispatcher. Only in case the material is not available in the warehouse.	Valid value	0	0
Once the material request is processed by buyer, the new value of delivery time (delivery_time_confirmed) is set or updated.	0	Valid value	0
The die is under renovation or manufacturing.	0	0	Valid value
The tool is ready for use.	0	0	0

Tool_assignments

This table expresses the tool assignments to individual production batches. The fields are: *ID_tool_item* and *ID_batch*.

6.2.4 Output Tables

The last section of the database tables is represented by the outputs creating the actual schedule. Many fields of tables in this section are automatically generated by the system, some other fields are designed to be modified by the planner.

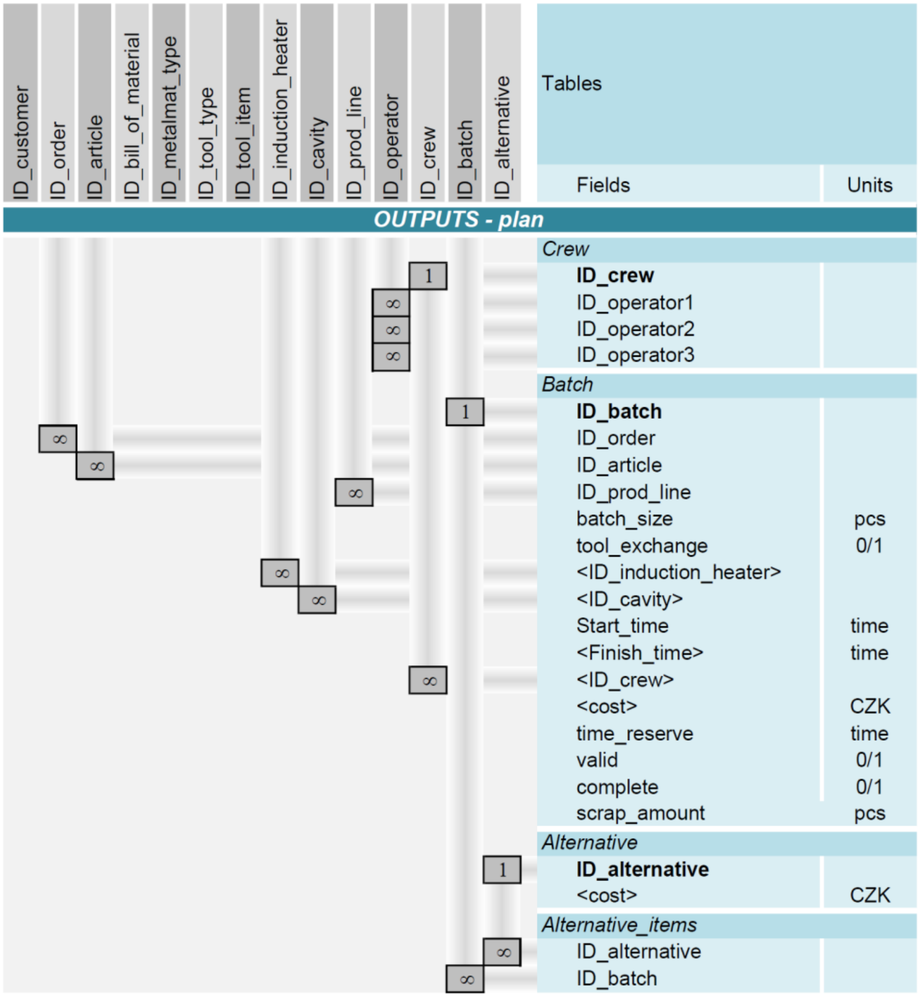


Figure 35 – Output Tables (own processing)

Crew

All the production lines are handled by specific crew consisting of three operators, one of them is usually a foreman of the production line. The composition and assignment of the crew to particular production line within a shift is conditioned by an operator’s qualifications. The crew is supposed to be established automatically, however there is still the possibility of an interactive modification provided by planner. Each crew is represented by a record in the table *crew*. The key is *ID_crew*. The record enumerates the three operators identified by their IDs.

Batch

The production batch is a group of products or material produced in a single production run. In the database, each batch is characterized by its individual *ID_batch*. Each batch belongs to one article (*ID_article*) required in order (*ID_order*). The batch includes defined amount of pieces (*batch_size*). The production is executed on given production line

(*ID_prod_line*) with optional induction heater (*ID_induction_heater*) and appropriate heating cavity (*ID_cavity*). During each batch production process, the tool exchange can be scheduled (*tool_exchange*). The intention is to define such a batch size, which allows maximum utilization of the used tool regarding its life cycle or durability. The batch production starts at the scheduled time (*start_time*) from which is derived the time of completion (*finish_time*). The time gap (*time_reserve*) represents the safety period prolonging the technologically necessary time for batch production. The production is accomplished by the crew (*ID_crew*) of each production line. The logical field *complete* keeps the information about the production completion. The amount of scraps in complete batch is characterized with the field *scrap_amount*. The fields valid and cost are present in the table for the purpose of planning. The logical field *valid* informs whether the batch is fixedly scheduled or not. The cost consumption for planning alternatives comparison is calculated from the field *cost*. This cost summarizes the operational costs (machine hour rates and wage rates of the crew). Once the machine is not operating (*tariff_machine_OFF*), this cost contributes the total alternative cost by means of special batch with zero article and zero amount, however with defined time reserve (the line is blocked from *start_time* to *finish_time*).

Alternative

The conditional, temporary, set of batches and batch related data creates a planning alternative. The planning alternatives are listed in the table *alternative*. The alternatives are identified by key field *ID_alternative*. The only additional field is *cost*, representing the cost demand for the alternative. The cost is calculated as a sum of all the production costs of all the batches creating the planning alternative.

Alternative_items

The detailed list of batches creating the planning alternative is defined by table *alternative_items*. Each record creates the relation between an alternative (field *ID_alternative*) and its batch (field *ID_batch*).

6.3 Algorithm based on Schedule Option Comparison

In purpose of the proposed planning and scheduling method, two database tables are essential – customer *order* and *batch*. The planning process takes the customer order as an input. Immediately after the order specification, the system starts its processing. The system automatically creates suitable set of production batches in accordance with relations and constraints defined by prescribed and dynamic tables of the database. As a result of such processing, the *batch* table is enlarged with set of new records. The evaluation of these records provides an estimated deadline of the order fulfillment. At the moment of order confirmation provided by a dispatcher, the order and its related records appear in the system as a valid data. According to the proposed planning concept, the basic planner role is to modify the batch attributes in order to create a reasonable planning alternative for any planning period. The planner is supposed to take into account customer's and order priorities. He also should follow the resources availability. Following this procedure repeatedly, the planner is able to create another planning alternative for the same planning period. The set of prepared alternatives is meant for further comparison. The planner choose just the one alternative from which he consequently selects the part corresponding to the intention planning period. Only the batches with accessible resources can be included into the schedule. Such selected batches are stated as accepted and then queued into the schedule (field *valid* in the *batch* table). This whole procedure is repeated for the next planning period.

The flexibility of the proposed system offers the option of long term planning providing better idea of cost demand assigned to individual alternatives.

The real production schedule is the initial part of the planning alternative. Such a planning procedure bears some signs of the Bellman-Ford principle.

7 PROJECT EVALUATION

The project provides the proposal of significant improvement of the existing ERP system functionality. The proposal advantage is that the solution comes out from the actual system. There is no need to replace the existing ERP, also the users' roles stay unchanged. Several new users' tasks were defined to streamline the information flow. The proposed solution presumes the modified ERP provides a support for fulfilling these tasks. The essence of the proposal is in improvement of abas functionality. The proposed planning and scheduling system is in accordance with the current planning and scheduling paradigm.

Due to the mention aspects, the project is feasible and it can be assumed the realization does not bring substantial difficulties neither in implementation nor in the user requalification.

The submitted suggestions are intended for further assessment of the company management. In this case, it is quite difficult to calculate any economic indicators such as profitability, return of investment etc. The starting-point for any economic calculations, only the labor costs associated with the proposed solution implementation have been specified and then calculated. The detailed information of labor costs summarizes the following table:

Table 6 – Supposed Costs for Project Implementation (own processing)

IMPLEMENTATION PHASE					
Job	***Number of Persons***	***Activity***	***Duration [hr]***	***Hour rate [CZK/hr]***	***Total cost [CZK]***
Programmer	1	Implementation	120	1500	180000
TRAINING PHASE					
Job	***Number of Persons***	***Activity***	***Duration [hr]***	***Hour rate [CZK/hr]***	***Total cost [CZK]***
Trainer	1	Training	12	1000	12000
Dispatcher	5	Education	10	130	6500
Buyer	1	Education	8	180	1440
Planner	1	Education	12	200	2400
Tool shop manager	1	Education	6	170	1020
Forge shop manager	1	Education	6	190	1140
TRIAL RELEASE & DEBUGGING PHASE					
Job	***Number of Persons***	***Activity***	***Duration [hr]***	***Hour rate [CZK/hr]***	***Total cost [CZK]***
Programmer	1	Testing & Debugging	20	1500	30000

In the implementation phase, it is required to hire an external specialist of the ERP vendor. It is assumed the time demand of all the activities related to the proposed solution implementation was estimated to be 120 hours (approximately 3 weeks of work). The hour rate of such a specialist is approximately 1500 CZK per hour. It represent the biggest expense in the table.

In the training phase, it is necessary to educate and train all the potential ERP users. The education and training is provided by the ERP vendor, hour rate of the trainer is 1000 CZK per hour. The introductory part of the training is common for all the users. The special advanced topics are supposed to be discussed in particular lectures. The auditory of each lecture is to be selected specifically. This arrangement of the training day enables to reduce training costs at minimum. It is supposed the planner undergoes the full time training due to the complexity of his job. The total cost of the training phase is supposed to be 24 500 CZK.

In the last phase of implementation, the trial version of improved planning and scheduling system is released. The trial version has to be tested and debugged in order to ensure proper functionality. The testing and debugging are provided by the external specialist of the ERP vendor as well. His hour rate is also 1500 CZK per hour. The costs related to this phase are approximately 30 000 CZK per hour.

The total expenses related to the proposed solution implementation are 234 500 CZK.

The revenues quantification is similarly problematic as was the case in costs. The majority of IT projects seems unprofitable in the short-term perspective. However, it is obvious that once the users become accustomed to the modified system functionality they notice a significant work relief due to the immediate availability of all the relevant data necessary for the effective performance of their duties. Another apparent benefit of this project is the quality increase of the processes management and the errors reduction within the planning and scheduling process.

CONCLUSION

The detailed concept of production planning and scheduling was introduced. In case of project realization, all the project aspects have to be discussed and further specified.

In the preparatory stage of the project, the current state analysis was worked out. This analysis revealed several significant shortcomings having the impact on effective, reliable and smooth execution of production data processing and further production planning and scheduling. The analysis provided substantial information about the relations among the activities of individual departments taking into account the attributes of all the entities in the production organization and production planning. The analysis was the starting point for the further proposal of production planning and scheduling process rationalization.

The proposal was focused on two areas. The first area resolved the issue of improving and streamlining data acquisition and data processing and sharing. The second area consisted of new planning and scheduling method based on planning alternatives comparison.

The first issue has been solved by redefinition users' performance within the ERP. On the one side, the users had to accept new tasks, on the other side the ERP should provide sufficient support for the tasks execution.

For the purpose of fulfillment the objective of the second issue, the new concept of planning and scheduling was outlined. The creation of planning alternatives enabled more flexible and efficient capacities utilization.

Realization of both issues lead to appropriate database definition. The designed database interconnected the input data, technological attributes, production constraints and dynamic production entities into one system that enabled the planning alternatives generation, their further comparison and final schedule creation.

The actual project implementation is associated with considerable costs on specialist involvement, staff training and education and finally the testing and debugging activities.

Such a complex project realization was quite a challenging experience. The project contained elements of process engineering, computing science and quantitative methods of decision making.

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Internal materials of Kovárna VIVA a.s.

LIST OF ABBREVIATIONS

AATP	Allocated Available to Promise
APS	Advanced Planning and Scheduling
ATO	Assembly to Order
ATP	Available to Promise
CEO	Chief Executive Officer
CODP	Customer Order Decoupling Point
CPM	Critical Path Method
CRM	Customer Relationship Management
CRP	Capacity Requirement Planning
CTP	Capable to Promise
DBR	Drum Buffer Rope
ERP	Enterprise Resource Planning
ETO	Engineer to Order
JIT	Just in Time
MIS	Management Information System
MPC	Manufacturing Planning and Control
MPS	Master Production Schedule
MRP I	Material Requirement Planning
MRP II	Manufacturing Resource Planning
MTS	Make to Stock
MTO	Make to Order
PTP	Profitable to Promise
SCM	Supply Chain Management
TOC	Theory of Constraints

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APPENDICES

APPENDIX A I: "D" PRODUCTION ORDER

Výrobní příkaz 231348

231348

Strana 1 z 1

Začátek	Konec	Datum vydání	Množství / ks	Zakázka	Datum tisku	Vytisknul
06.04.16	06.04.16	29.03.16	**0**	**00828070**	06.04.16	Paseková

D00828B **00828A**

Vícekus	Vydáno	Hm / kus
Ne	kg	XY kg

Poznámka výrobního příkazu: Tavby: Mat.

Poznámky dílu:

Odstranit otřep: ANO

Úroveň kontroly:

Oddělit tavby: Ano-zákazník
Insp. Cert. EN10204: ANO (vzorkování)

Kopie orig. atestu: Ne
Rozměrový protokol: Ne

Protokol o tep. zprac.: Ne
Zkouška rázem: Ne

Zkouška tahem: Ne
A (D-díl): Ne

Pol.	Polotovar / operace	Vzít ze skladu	Množství / čas
	M25CRMOS4_D60/B	**HM83/1**	0 kg
	25CrMoS4		

SkladMísto	Číslo šarže	Množství

231348001

DN_CADDY140
Dělení na nůžkách CADDY 140

Seřízení: XY min **0 min**
Takt: XY s
Norma za směnu: XY Ks

Naskladnit do
D01KOLEJ1

Datum	Tavba	Počet kusů	Datum	Tavba	Počet kusů

APPENDIX A II: “K” PRODUCTION ORDER

Výrobní příkaz 232130

232130 Strana 1 z 1

Začátek	Konec	Datum vydání	Množství / ks	Zakázka	Datum tisku	Vytisknul
07.04.16	10.04.16	06.04.16	**4.210**	**00828069**	06.04.16	Paseková

K00828A **00828A**

Vícekus	Vydáno	Hm / kus
Ne	Ks	XY kg

Poznámka výrobního příkazu:

Tavby: Mat. 25CrMoS4
T37727/2016 - 15870kg (pro 4221Ks přířezů)

Poznámky dílu:

Úroveň kontroly: A

Oddělit tavby: Ano-zákazník
Insp. Cert. EN10204: ANO (vzorkování)
Kopie orig. atestu: Ne
Rozměrový protokol: Ne
Protokol o tep. zprac.: Ne
Zkouška rázem: Ne
Zkouška tahem: Ne
A (D-díl): Ne

Pol.	Polotovar / operace	Vzít ze skladu	Množství / čas
	D00828B 00828A	**D01KOLEJ1**	4210 Ks

SkladMísto	Číslo šarže	Množství

232130001 **QMK** Seřízení: XY min **0 min**
Mezioperační kontrola Kovárna

232130002 **K02** Seřízení: XY min 1474 **min**
Kování LMZ1600 Takt: XY s
Následující operace: Zušlechtění na Realistic Norma za směnu: XY Ks

Naskladnit do
K01ZAKOVARNOU

Datum	Tavba	Počet kusů	Datum	Tavba	Počet kusů

APPENDIX A III: "VR" PRODUCTION ORDER

Výrobní příkaz 230573

230573 Strana 1 z 1

Začátek	Konec	Datum vydání	Množství / ks	Zakázka	Datum tisku	Vytisknul
31.03.16	31.03.16	18.03.16	11	00828066/1	06.04.16	Paseková

VR00828A **00828A**

Vícekus	Vydáno	Hm / kus
Ne	2.040 Ks	XY kg

Poznámka výrobního příkazu:

Tavby: Mat.
T27886/2015 - 6100kg (pro 1622Ks přířezů)
T32575/2015 - 8716kg (pro 2318Ks přířezů)

Poznámky dílu:

Úroveň kontroly:

Oddělit tavby: Ano-zákazník
Insp. Cert. EN10204: ANO (vzorkování)
Kopie orig. atestu: Ne
Rozměrový protokol: Ne
Protokol o tep. zprac.: Ne
Zkouška rázem: Ne
Zkouška tahem: Ne
A (D-díl): Ne

Pol.	Polotovar / operace	Vzít ze skladu	Množství / čas
	K00828A 00828A	**K01ZAKOVARNOU**	11 Ks

SkladMísto	Číslo šarže	Množství

230573001 **H010101** Zušlechtění na Realistic - A
Seřízení: XY min — 3 **min**
Takt: XY s
Norma za směnu: XY Ks

230573002 **T02** Tryskání STEM B10,B12,PT 63A
Seřízení: XY min — 1 **min**
Takt: XY s
Norma za směnu: XY Ks

230573003 **Q0402** Kontrola trhlin - 2. pracovníci
Seřízení: XY min — 0 **min**
Takt: XY s
Norma za směnu: XY Ks

230573004 **Q0101** Výstupní kontrola A
Norma za směnu dle CEZ: XY ks
Seřízení: XY min — 3 **min**
Takt: XY s
Norma za směnu: XY Ks

Naskladnit do HOTOVE

Datum	Balení	Dobré	Zmetky	Odchylka	Podpis	Poznámka