Professional MBA
Automotive Industry

Proposed Approach to Implement Industry 4.0 for Custom Production in Engineering

A Master's Thesis submitted for the degree of "Master of Business Administration"

supervised by
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Bratislava, 28.09.2017

Affidavit

I, **RADOMÍR SLUK**, hereby declare

1. that I am the sole author of the present Master's Thesis, "PROPOSED APPROACH TO IMPLEMENT INDUSTRY 4.0 FOR CUSTOM PRODUCTION IN ENGINEERING", 70 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
2. that I have not prior to this date submitted this Master's Thesis as an examination paper in any form in Austria or abroad.

Vienna, 28.09.2017

Signature

Acknowledgment

I would like to thank my supervisor Ing. Peter Magvaši, CSc., for assistance and support in the processing of the master thesis, for his valuable advices and insights and also for accelerating my activity. At the same time, I thank all my colleagues and friends who have given me the necessary energy to the work.

Abstract

One of the key indicators of the future for enterprise productivity growth is Industry 4.0 and the implementation of its elements. To achieve this goal, custom manufacturing is specific as one of the types of production. The proposed solutions of the master thesis deal with the issue of methods for increasing productivity in the custom manufacturing of the engineering company, which are applicable also in the companies, where production is realized according to the customer requirements. The theoretical part focuses on the Industry 4.0 concept, the description of the digital enterprise of the future, the comprehensively estimated savings after the introduction of Industry 4.0 elements and the basic management tools. In the practical part, data flows in the production process are designed and identified with the aim to optimize and distribute these data for the feedback in the production process. Standardization and harmonization of programs on CNC machines is another important topic of the master thesis. For evaluating the performance and quality of CNC machine production process, methods and statistical reports by introducing OEE and by visualization in the production facilities of the company have been used. Monitoring the capacity utilization and performance of CNC machines is one of the indicators to increase productivity in production. In the work, innovative changes in custom manufacturing are defined and implemented as a creation of basis for the use of Industry 4.0 elements. The aim of the master thesis was to realize to increase the efficiency and to improve the KPI indicators of the custom production types by implementation of used methods.

Table of Contents

1 INTRODUCTION

Many years of working in the industrial company MATADOR INDUSTRIES, a.s., Dubnica nad Váhom for the purpose of maintaining a permanent sustainable growth of competitiveness on the market of the automotive, engineering and electrotechnical industry has led to postgraduate study in the program "PROFESSIONAL MBA AUTOMOTIVE INDUSTRY" organised by TU WIEN and STU Bratislava.

The company MATADOR INDUSTRIES, a.s. is the part of one of the leading Slovak manufacturers in the automotive and machinery industry, MATADOR HOLDING, a.s. It is an engineering company that provides a wide range of production components, nodes and single-purpose machines. The production base consists of precision CNC machining, turnkey solutions, development, and construction, supported by high quality standards. The company‘s advantages are many years of experience with machining, such as drilling, milling or turning. The modern machinery equipment together with qualified and experienced human resources can meet the individual customer requirements for products of various materials, complex shapes and sizes. This is also facilitated by the actual development of the construction and technology of single-purpose devices and their production and a complex supply to the various industries.

1.1 Objectives of Master’s Thesis

The Master´s Thesis comes out from the knowledge that businesses are a socio-technical complex. They are defined by a set of resources, products, processes, operations, activities, schedules and events. This set responds to the external environment, which is mainly driven by the needs, wishes and opportunities of customers on the market. The deepening of the globalization of human civilization creates a constant push for rapid and effective adaptation to the market situation in different parts of the world, in various cultural and social structures. An enterprise, as an organization in which human activity such as entrepreneurship is assured, evolves in connection with human development. This is related to the new generation of products that are associated with the new generation of production systems, which requires a new management system for an organization such as an enterprise. This development is characterized by the high efficiency of the transformation process that responds flexibly to the market. This influences the amount of production and product variation. A classic approach to projection and implementation of mass-production production systems with low product variants goes to a different way of designing, implementing and managing. These are referred to as individualized mass production. It is not just a proposal for the placement of machinery and equipment associated with the flow of material, but especially new technological processes, new materials, but also a different flow and processing of data, information and knowledge. It is a basic prerequisite for the individualization of mass production. The search for the optimal variant of the production system is one of the dominant tasks in the management of the industrial production of a new generation.

Progress in processing information, in particular its digitization, has created conditions for enterprise governance innovation. It affects all phases of product life. Improvement of information and communication technologies enables full application of enterprise management concepts such as Computer Integrated Manufacturing (CIM), Computer Aided Design (CAD) and Computer Aided Production Preparation (CAPP) that have grown into the concept of DIGITAL ENTERPRISE. This concept is a fundamental innovation element of the company of the future. The scientific roles for exploring of the digital enterprise as a basis for the company of the future are the subject of extensive research projects. Advances in research and in practice of the methods and techniques used in the digital enterprise concept have led to an improvement in its model, structure and performance in particular. These improvements have led in parallel to the formulation of the fourth-generation industry known as INDUSTRY 4.0.

The global economic crisis that broke out in 2008 also hit major industrial sectors around the world. The impacts of these crisis have been directly reflected in the business environment, which naturally changes constantly. This fact must be addressed by enterprises through their internal changes so that they are competitive with other businesses. Many countries and global industrial companies have responded to these changes by launching initiatives not only to get lost positions, but to create management models that reduce the risk of a sharp loss of competitive ability in the market. From a geopolitical point of view, the aim of these initiatives is not only to improve the competitive position of industry, but also the need for industrial enterprises to continually improve and increase competitiveness in global markets. One of the key initiatives for the industry in Europe is the initiative of the European commission with the name of the Enterprises of the future. This initiative brings in addition to the response to the economic crisis also the idea of the introduction of new technologies in enterprises. The aspect of the use of new progressive technologies along with advanced industrial engineering brings new options for increasing the chances of success on the market for the companies. Enterprises of the future and advanced industrial engineering are based on the mutual symbiosis, where the technology used in the enterprise of the future using advanced industrial engineering are bringing new possibilities for planning and business management.

If MATADOR INDUSTRIES, a.s. wants to compete competitively in its market, it must meet these generally valid tendencies. It does not just adapt the production base, but in particular, it will innovate complex management of all the processes. It is necessary to take some gradual steps to create the potential for using advanced industrial control systems as described in the INDUSTRY 4.0 concept. This situation can be addressed by introducing a comprehensive standardization, operational production management as a comprehensive tool for effective value creation of the enterprise as a whole, and management of the entire supply chain. (Tomek G., Vávrová V., 2014, p.349-350). These aspects have been taken into account when formulating the subject of the work, formulating the scientific task the Master´s Thesis deals with. To determine the thesis, I come from these hypotheses, to which the structure of the thesis has been subjected.

The above is the scientific role of this thesis. It is:

Production process innovations in the classic make-to-order engineering production for the creation of basic conditions for the application of the principles of INDUSTRY 4.0.

To solve this scientific task, these hypotheses are needed:

1. In order to create the conditions for starting the application of the principles of INDUSTRY 4.0 in traditional business entities, the transition phase is necessary.

2. The dominant phase is the standardization of data and information flow throughout the whole production process in connection with other company processes.

To confirm these hypotheses the following will berealised:

- Identification of data flows in the production process, optimization and distribution of this data in order to generate feedback for the production process in connection with other company processes
- Standardization and alignment of programs for CNC machine control at individual workplaces
- Summary of statistical reports about individual workplaces of CNC machines for evaluating the performance and quality of the production process
- Use of smart technology for internal material tracking for the Welding section

The implementation of the proposed solutions will have an immediate practical impact on company performance and will be reflected in the different areas of the company as follows:

- Planning area - reduction of the necessary production man-hours by 3% over the next 3 years
- Manufacturing area - increase in machine capacity by 2% per year
- Maintenance area - reduction of unplanned downtime caused by machine and equipment failures by 3% per year
- Monitoring area - monitoring data from OEE of individual machines and consequently taking measures to increase the efficiency of the run time of CNC machines

The thesis is divided into six parts. After the introductory part the analysis of INDUSTRY 4.0 concept is dealt with, in the third part a work model to achieve the goal of the work is defined. The fourth part deals with the implementation of the individual models. The benefits of the solution and the expected results of the actual practice are summarized and discussed in the fifth part. In the final chapter the learned results and knowledge are summarized and the key factors of the INDUSTRY 4.0 concept for use in practice are outlined.

2 THEORETICAL KNOWLEDGE ABOUT THE LATEST TRENDS

Techniques and methods of advanced industrial engineering that are created by the implementation of innovative and breakthrough technologies included under the name of digital and knowledge engineering, which creates an equally and stably competitive environment for the company's sustainable competitive ability. This is achieved by integrating digital data from engineer designing, modeling, prototyping, project designing and processing into a virtual enterprise using simulation and operational management. Thus real-time business models, their simulations, and decision-making processes using graphical tools are effectively applied. This evolutionary process has its interdependent activities that need to be gradually implemented into corporate governance.

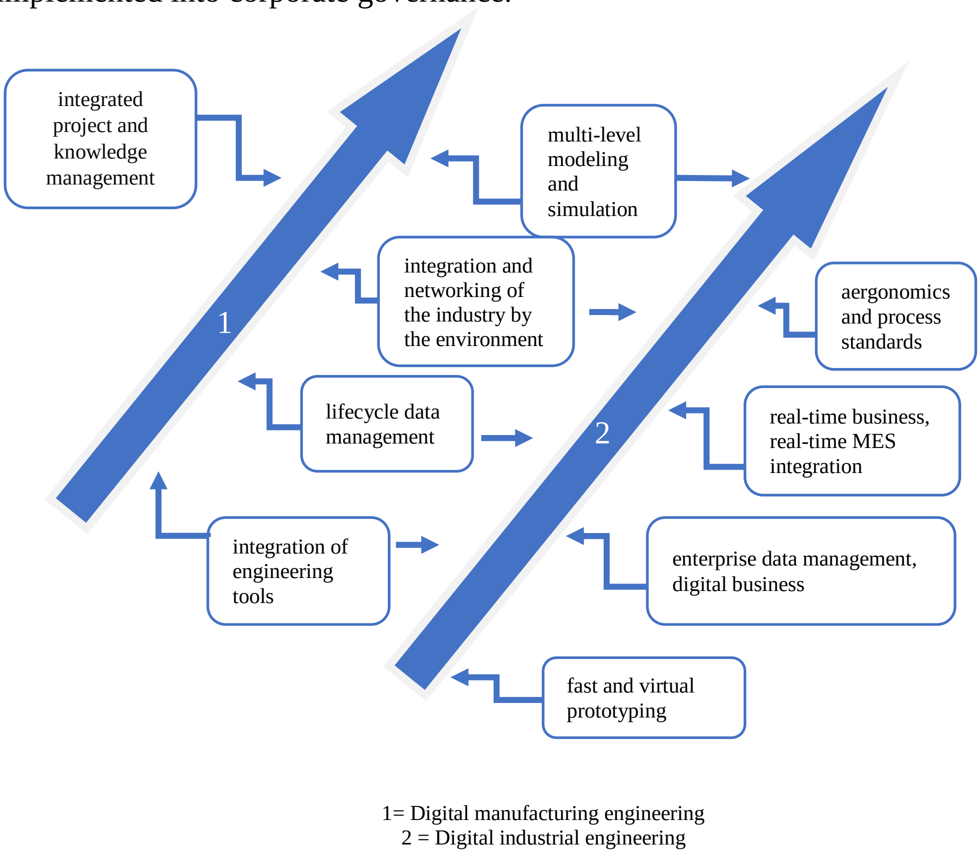

Fig.1 - Digital and knowledge engineering

The procedure for achieving such a complete process is illustrated in Fig. 1 (Jovane, F. et al, 2009, p.134). The time sequence of the solution and application of individual technologies in real business is shown in the picture from the beginning of the arrow to its end. Planting and adopting of individual technologies in a real business has the character of short, medium and long-term goals, while their system solution and interconnection creates the conditions for a sustainable competitive ability of the enterprise.

From the point of view of the generation and processing of data from production processes, three types of autonomous systems have been and are currently being used in business practice:

- Administration and management of large volume data systems from centrally organized centers focusing on material and resource planning, in abbreviations such as MRP or ERP systems
- (CAx) - Graphical Interactive Systems for Development of Product, which includes product data administration through sorted product models
- Flexible automation of processes distributed in networks of mechatronics such as: machines, robots, devices and lines - which have control and monitoring systems, which are also called MES

Their autonomy generates frequent breaches of information flow, obsolescence and in particular, inflexibility of managing business processes as a whole. According to ManuFuture, in prospective technologies for future generations of the industrial and European production system, digital engineering technologies are in the category of advanced industrial engineering. A set of advanced industrial engineering techniques and procedures creates a system collectively called the Digital Enterprise. The Association of German Engineers (VDI - Verein Deutsche Ingenieure) defines a digital enterprise as a concentrated expression for large-scale networks of digital models, simulation methods and tools and three-dimensional visualization integrated with complex data management. The aim is to plan, evaluate and continuously improve all known structures, processes and resources of the real enterprise in connection with the product (https://www.beuth.de/de/technische-regel/vdi-4499-blatt-1/98982846). It is the result of the incremental development of the functionality of production systems in response to changes in economic and social relations, in particular the emergence of new breakthrough technologies coupled with the rapid boom of new information and communication technologies. The advances made in the 1970s and 1980s resulted in the relationship between machine and man - like YOU and YOU (Warnecke, H.-J., 1999, p.26). In the short term point of view competitiveness in the market is an important element for sustainable competitiveness. (Jovane, F., Westkämper, E., Wiliams, D., 2009). This is achievable by conventional industrial engineering tools that affect costs and production. However, in terms of medium-term sustainable competitiveness, it is necessary to use technologies that provide leadership in advanced industrial engineering technologies. These create the preconditions for creating global production as a precursor to a knowledge-based economy. Digital engineering technologies are a fundamental source of leadership in the industrial sectors, as a basis for sustainable competitiveness in the future as well. The development from the flexible production systems to the enterprise of the future, as well as the individual key milestones are in Fig. 2 (Westkämper, E., Bauernhansl, T., 2014, p.14).

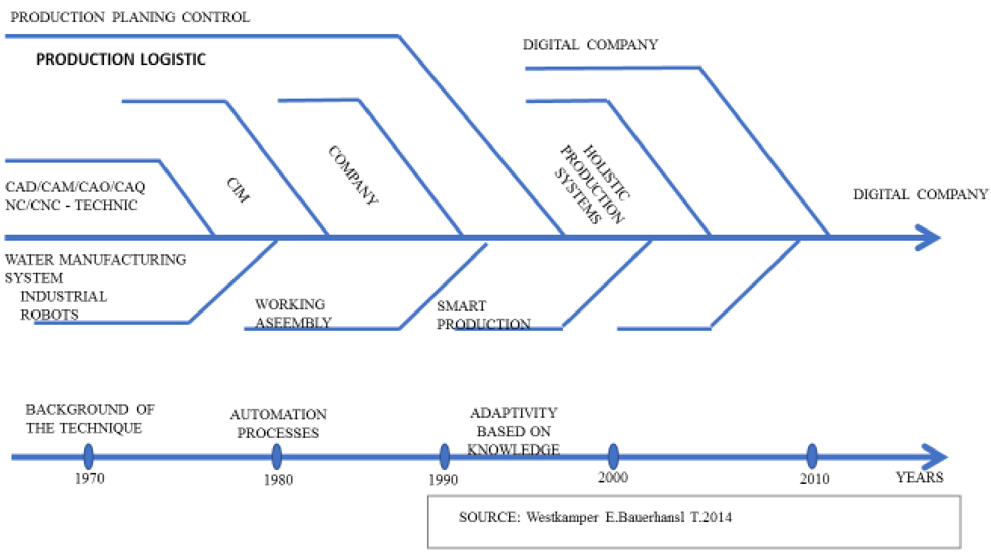

Fig.2 - Development lines of production systems

In the European Union, the direction of industrial policy is geared towards a gradual and purposeful build-up of the concept of factory of the future. In the research and innovation strategies by the 2030 year, direction towards these six areas is assumed:

- advanced manufacturing processes

- adaptive and intelligent manufacturing systems
- digital, virtual and resource-efficient enterprise
- collaborative and mobile business
- human as production center
- customer-oriented production

(http://www.effra.eu/)

In the digital enterprise, all digitized data is integrated with each other, allowing for smooth editing of real processes with digital presentations, which can be discrete or smooth in time. The goal of using digital enterprise methods is to create prerequisites for a dynamic view of the production in the enterprise. This is the use of the digital data of the original enterprise, with its material structure along with the mobile and static means, the processes in it, the real current state of the company elements and sets. They are transformed into a model and virtual form, with the potential for change in all the company systems. These relationships are illustrated in Fig. 3 (Westkämper, E., 2013, p.109). The diagram shows the dominant role of data management, which supplies modeling and simulation processes, smooth adaptation processes, including the implementation and deployment of an effective model in a real enterprise.

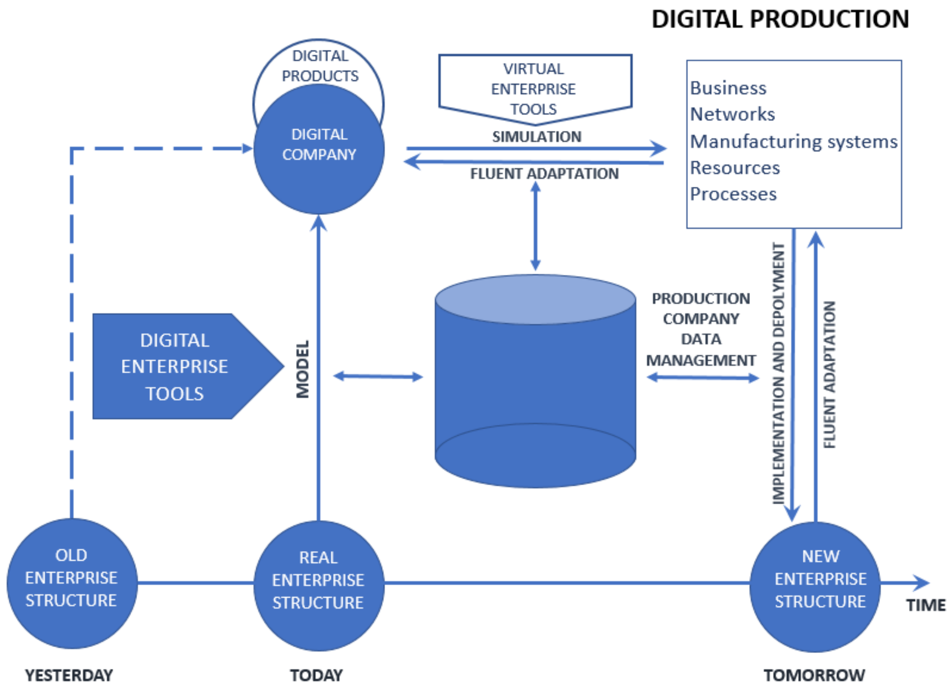

Fig.3 - Relationships between Real, Digital, and Virtual Enterprise

(Source Westkämper, E., 2013, p.109)

By using such a model of real, digital and virtual enterprise relationships, it is possible to effectively increase the basic objectives of the company and its subject of business. This enables market success, in particular by optimizing costs, quality, time and meeting customer needs. To achieve this, methods such as modeling, simulation, optimization, visualization, documenting and communication are used. ERP systems are used as tools, employing special programs based on the CAx principle.

Technological advances have created the conditions for a new structure and the nature of the industry. This is achieved by the evolutionary changes induced by modern technologies and information technologies in the original industrial processes, on the one hand and on the other hand, it is a revolutionary change towards the cyber physical systems (CPS), which at the higher innovation stage integrate and comprehensively apply the achieved evolutionary process. This new qualitative level of industry is referred to as the fourth industrial revolution, in short INDUSTRY 4.0, or SMART INDUSTRY. The core of this industry is SMART FACTORY. This is the next stage of development, utilizing the results achieved in the concepts of digital and virtual enterprise.

In the economically advanced countries, national programs or national platforms that target the issue of major innovations in industry (Fig. 4) are created to speed up the process of deploying cyber - physical systems. This creates prerequisites for the massive effective deployment of innovation at all levels of industrial enterprises and other parts of the society for lasting competitive ability.

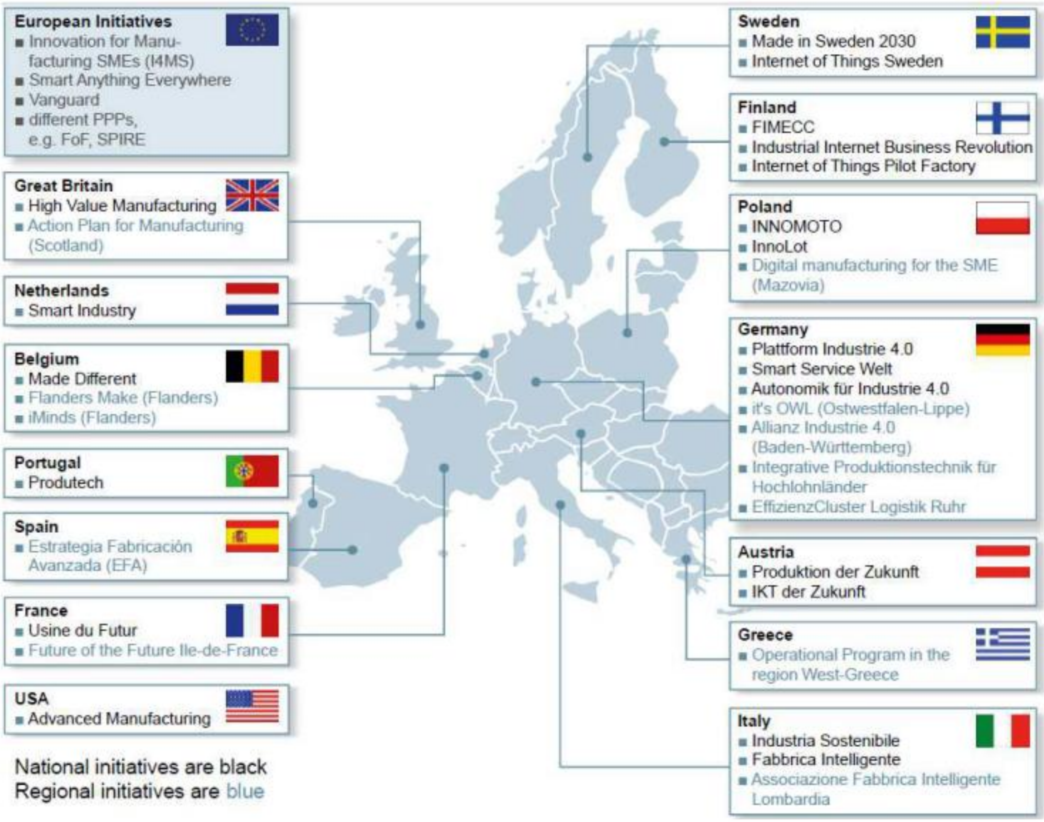

Fig.4 - An Overview of National and Regional Initiatives in the EU

(*Source Dumitrescu, 2015*)

Countries with the best and comprehensively sophisticated programs include Germany, Austria, Switzerland and the USA. In the Federal Republic of Germany it is PLATTFORM INDUSTRIE 4.0 (http://www.plattform-i40.de/I40/Navigation/DE /Home/home.html), INDUSTRIE 4.0, NATIONAL INITIATIVE INDUSTRY 4.0 in the Czech Republic (https://www.mpo.cz/assets/dokumenty/53723/64358/658713/ priloha001.pdf), in Austria in 2015 Industrie 4.0 Österreich was founded - die Plattform für inteligente Produktion (http://plattformindustrie40.at/uber-den-verein/#ziele), in Switzerland the INDUSTRIE 2025 (http://www.industrie2025. ch/industrie-2025.html), initiative, in the US it is the consortium INDUSTRIAL INTERNET CONSORTIUM (http://www.iiconsortium.org) and SMART MANUFACTURING LEADERSHIP COALITION (https://smartmanufacturing coalition.org/).

Estimated savings through the introduction of INDUSTRY 4.0 (Bauernhansl, T., 2017, p. 27) are shown in Table 1. This is the cost of storage, manufacturing costs, logistics costs, total cost of quality, maintenance costs. As can be seen from the expert estimation, the greatest savings can be achieved through by introduction of the INDUSTRY 4.0 elements in the total cost, where the estimated saving potential is -60% to 70%. This only confirms that the greatest benefit of the INDUSTRY 4.0 concept is in its complexity. To achieve this, it is necessary to solve the technical problems of connecting the sensors to the computer hardware and the necessary non - standard computer program, which as a whole can communicate with other similar elements, nodes and components of the cyber - physical system.

COSTS	EFFECTS	POTENCIAL OF COSTS REDUCTION %
Storage costs	*Decrease of security costs*	**from -30 to -40**
	Avoiding "BULLWHIP and BURBIDGE" effect	
Construction costs	*Increase of OEE*	**from -10 to -20**
	Process loops	
	Improvement of horizontal and vertical flexibility of personnel	
Logistic costs	*Rise of automatization degree*	**from -10 to -20**
Total costs	*Expansion of leading competences scale*	**from -60 to -70**
	Reduction of disagreements	
Qualitative costs	*Quality on processes in real time*	**from -10 to -20**
Maintenance costs	*Optimalization subsidiary parts*	**from -20 to -30**
	Identification of maintenance stage (procedural and measured data)	
	Dynamic preceding	

Table 1 - Estimated cost savings when introducing INDUSTRY 4.0 elements

The forecast of savings achieved by the INDUSTRY 4.0 concept is based on the idea that cyber - physical systems are a complex object. There is an interaction of individual devices, processes and activities of people that are characterized by fixed and changing data in real-time. The management of these data is the basis for the decision-making and management processes of the industrial enterprise as a whole. In this process, the principles of industrial engineering are irreplaceable. This requires a new generation of industrial engineering methods and techniques, based on digital and knowledge engineering, using in particular experience of the practical use of digital enterprise methods.

An essential feature of INDUSTRY 4.0 is the aggregation of engineering and operational information of various projects, equipment and machine operations at different levels of production. Cyber - Physical Systems (CPS) are a basic element of this aggregation, and the processes of automation of these systems in the context of INDUSTRY 4.0 need to be examined in the following aspects:

- Cyber-Physical systems architecture
- Smooth data communication in real-time engineering processes
- Intelligent product integration with intelligent manufacturing systems
- Data integration in CPS for preparing data for operators

Model architecture in conjunction with communication is a bearing prerequisite for intelligent production systems. The variety of cyber-physical systems is driven by the targeted processing of data necessary for the work of engineers and operators so that the equipment performs the processes most efficiently. From these views, cyber-physical systems, as the basis of INDUSTRY 4.0, are characterized by:

- By the means of sensors, physical data is immediately recorded and in reverse provides information for correcting of physical, chemical, biological processes
- Saved data that is the basis of active and reactive integration of the physical and digital world
- By a fixed or wireless interconnection, they create a local and global digital network
- Data, information that is available as a service globally
- The dispositive multimodal line of HUMAN-MACHINE-INTERFACE providing communication and management options such as speech and gestures

Direction to industry type characterized as INDUSTRY 4.0 is very complex and interdisciplinary. Its effective and gradual application in real industrial practice is mainly related to the comprehensive understanding and uptake of all changes from a holistic point of view, exploring all contexts. This implies an understanding of the essence of new and breakthrough technologies, their potential and breadth of induced changes in existing corporate culture and their impact on the whole business model in society.

This is also related to a deeper exploration of evoked social changes, the standing of man in such an environment. The use of new breakthrough technologies and their applications will not only affect one industry but will be matched by a very wide range of processes, relationships, products, goods and specific services.

INDUSTRY 4.0 focuses on the production of intelligent products, methods and processes called SMART PRODUCTION, implemented in an organization called SMART FACTORY. They are characterized by complexity with small deviations and rising production efficiency. In intelligent company, people communicate with machines and resources through social networks where intelligent products are produced. All this is achieved by intelligent mobility, intelligent logistics with intelligent energy networks, as intelligent enterprise infrastructures. The basic element of this comprehensive system is cyber-physical systems. They use modern technologies such as Cloud Computing, Big Data, Data Mining, Internet of Things and Internet of Services (IoT, IoS). All this allows for more effective deployment of new technologies such as nanotechnologies, 3D digital data, powder metallurgy with controlled component properties.

Cyber - Physical systems are based on qualified data management, using the In - MEMORY database architecture and technology, the Internet of Things and Internet of Services, cloud storage of massive numbers of data and their choice. Today's current state of management in connection with the use of classical data management, especially in ERP systems. The future, where CPS elements are already in business deployments, is based on the fact that management features are part of the global data cloud. (Lechler, A., Schlechtendahl, J., 2017).

In CPS there is interaction between different levels of control processes and used programming tools. The cyber - physical system includes the manufacturing equipment and the corresponding components based on the electronic elements, including their software, while this whole unit communicates with the operating system.

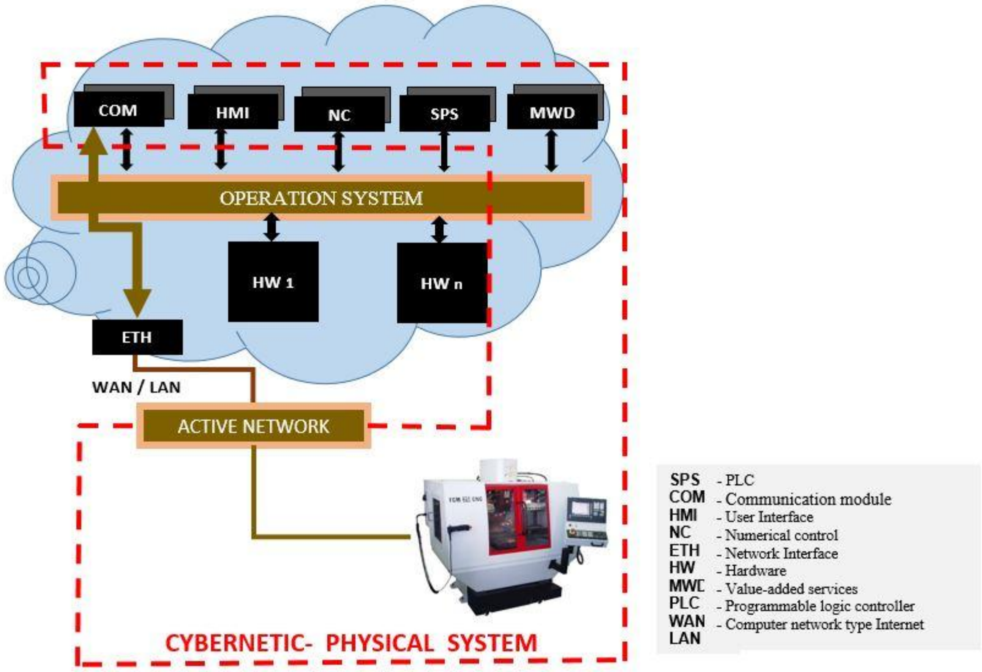

Fig.5 - System boundaries for the cyber - physical system

(Source Lechler, A., Schlechtendahl, J., 2017, p.33)

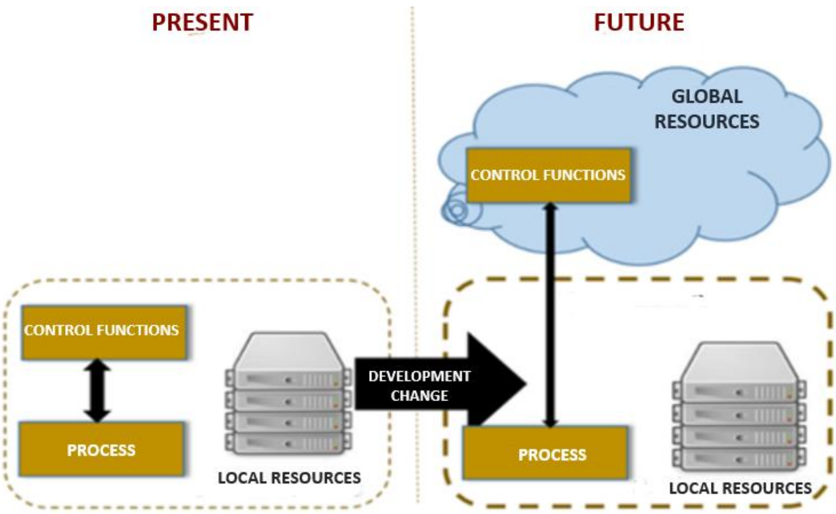

Fig.6 - Changes to data processing in data cloud

(Source Lechler, A.,Schlechtendahl, J., 2017, p. 66)

The new digital enterprise concept uses the principle of linking the product lifecycle areas through data management, the core of which is the In Memory database. This is a prerequisite for processing large enterprise data. The interfaces of each area are based on the service delivery principle through the integration platform. At the same time, sensory data is created on the principle of Internet of Things and Internet of Services, producing large volumes of data.

Entreprises are a complex socio-technical complex that is defined by a set of resources, products, processes, operations, activities, plans and events. This set responds to the external environment, especially the needs, desires and capabilities of customers in the market. A new generation of products is usually only efficiently created by a new generation of production systems. Their characteristic is the high efficiency of the transformation process associated with a flexible time response to the situation in the market. This affects the amount of production and product variation. Thus, the classic approach to the design and implementation of production systems for mass production with low product variants goes to design and implementation, which is characterized as individualized mass production. It is not just a proposal for the placement of machinery and equipment linked to the flow of material, but especially new technological processes, new materials, but also the flow and processing of data, information and knowledge, which is a basic prerequisite for the individualization of mass production. An efficient production system is a compromise between production volume and product variants. The process of finding an optimal production system variation is one of the dominant tasks in managing industrial production for success on the world global markets.

The connection of devices, digital models and sensory systems is the Internet of Things. The Internet of Things and its opportunities is a great potential for increasing productivity in the future. The communication of machines, logistics facilities and material has the potential to replace corporate governance.

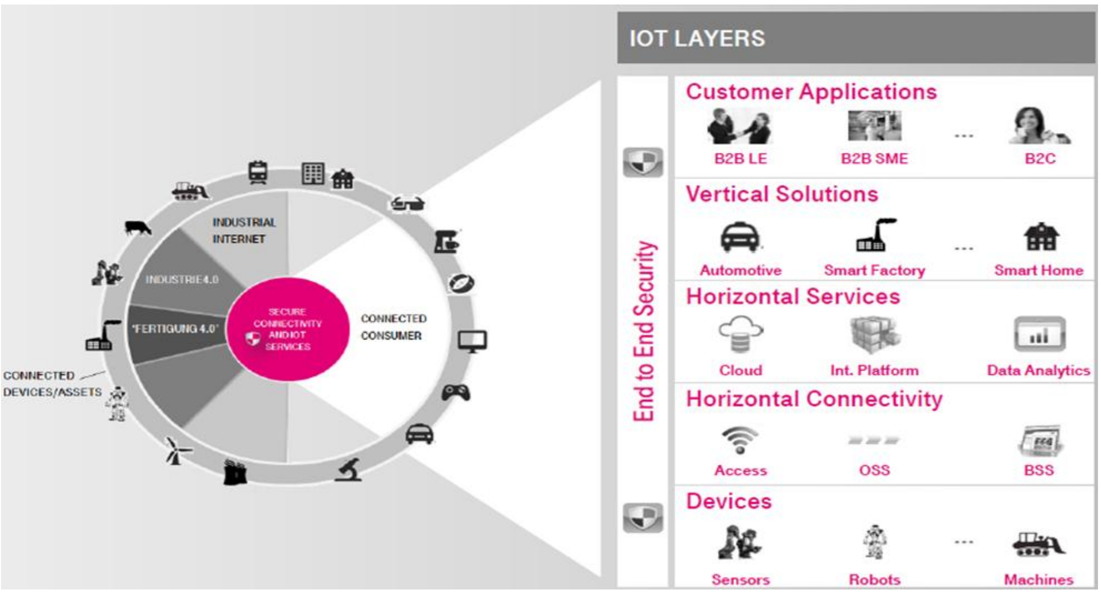

Fig.7 - Internet of things – Structured in Layers

*(*Source *Planning workshop International sales may19 th 2016 T – system presentation*)

Customer applications, vertical solutions, horizontal services, horizontal connectivity and devices (Fig 7). The segments that the manufacturing companies see as offerin greatest potential for Benefitting from the Indutry 4.0 include research and development (in which a total of 78% of companies see great potential), warehousing and logistics (74%), production (73%), services (72%), purchasing (69%) and sales (56%).
(DELOITTE manufacturing-industry-4-0-24102014)

The nature of production in company Matador, Industries a.s., shows that a large number of diverse factors affect the efficiency of business. It is shown that in order to solve the continuous improvement of business efficiency it is not possible to use the methods of operative planning according to the rhythm of withdrawal, according to numbers, in periodical batches, in batches according to production security by supply of components, according to cycles or production time. Planning based on customer orders, which is characterized as piece production, while optimization being achieved by using a logical framework with variable elements. (Gregor, M., Mičieta, B., Bubeník, P., 2005, p.12-14) It is the production of a large number of products of different shapes, dimensions, material, input semifinished product. Its progress is repeated irregularly and in some cases it is not repeated at all. This uniqueness enforces the great universality of each high-qualified worker facility. It is made exclusively on order. (Libal, V. et al., 1971, p. 14-29).

The theme of the Master´s Thesis is the natural outcome of the research, practical consultations and other theoretical and practical activities. The content is focused on the concept of Industry 4.0, which is a challenge for technological and communication systems in the production process. Despite the digitization and automation, creativity and tendency to experimentation will still remain irreplaceable in the future.

2.1 Why Industry 4.0?

Industry 4.0 is identified as the fourth industrial revolution, its goal is a SMART FACTORY that is characterized by the use of the necessary digital resources, respecting security and safety at work, ergonomics. The necessity of Industry 4.0 is to customize products for users according to the latest developmental and technological knowledge, at high flexibility, human factor involvement and utilization of automation technology. (Tomek, G., Vávrová, V., 2017, p. 10)

Manufacturing enterprise of the future will be characterized by intelligent and flexible processes where individual building components will communicate independently with production facilities, which will be interconnected by networks.
There is a question to ask: A robot or a man? The answer is: a man.

In the smart enterprise of the future, the idea of the production hall, where the new product will be generated by only a robot, is unthinkable and unreal. The role of man remains irreplaceable.
The following factors are key to increasing of the company's productivity:

- Digitization
- New production technologies
- Network connection
- Flexibility, mobility and infrastructure
- Training and enhancement of employee qualifications

Trends and requirements for the flexibility of industrial production create the conditions for development of new effective processes and solutions. These include the digitization of the production process and the produced products, including changes in business models and the shifting from products to product-oriented services.The purpose of this digitization is to make a vital contribution to meeting the EU's intention to increase added value in industry from today's 15% to 20% of gross domestic product.

All these digitization processes and changes are the part of the so-called 4th Industrial Revolution, characterized by the increasing digitization and mutual interconnection of products, value chains and business models.

The Industry 4.0 concept is a European response to ongoing changes and at the same time, it is the answer to the question of how to keep European industry competitive despite all threats.

Smart Factory "SMARTFact" is currently focused primarily on the carrying out of industrial research and experimental development in the areas of global networks that interconnect production facilities and other objects of the industrial enterprise into CPS (Cyber-Physical Systems) according to the concept of Industry 4.0.

The research of CPS - the basic building blocks of "smart factories", focuses on the creation of the functionality of the autonomous exchange of information, the necessary actions in response to current conditions and mutual independent review. The interconnection of information generated by sensors, machines, machine parts and research in the area of integration and IT systems across the value chain extends beyond the borders of companies. The CPS interconnected in this way will be using the standard communication protocols based on the Internet (in the concept of the Internet of Things) and will mutually respond to, and analyze data, in order to anticipate possible errors or faults, automatically configure and adapt to the changing conditions in real time.

Research into the integration of objects into the CPS will be primarily driven by the research of distributed control systems, co-ordination of activities and cooperation between autonomous subsystems. In this belief, all processes, communication and coordination will have a decentralized status.

2.2 Operational management of production

Basic managerial tools for operational management are:

- Definition of goals
- Planning
- Organizing
- Managing
- Controlling

At an operational level of production management, the focus must be on the following areas:

- Operational planning
- Operative records of production
- Methods of operative management of production and purchase
- Controlling
- Change management

Operational planning – is a complex of operational planning of different time levels from the factual point of view /sales, manufacturing, purchase/ or from the point of view of the time /quarterly, monthly, weekly, daily, change/.

The operational records of the production – is the basis of the records of the different types of agenda /non-compliant products, quality control, production-technological documentation/. (Tomek, G., Vávrová, V., 2017, p.37, 38)

Methods of Operational managing of Production and Purchasing:

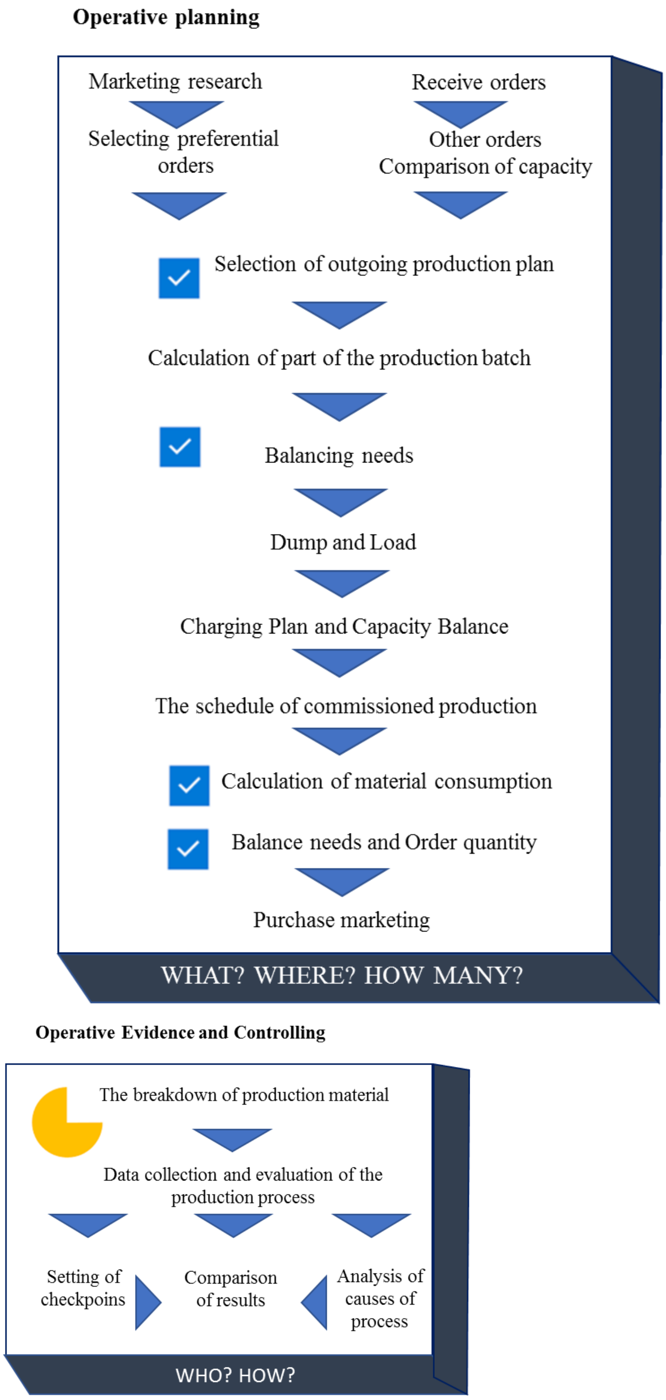

Fig.8 - Operational control of production

(Source Tomek G., Vávrová V., Prumysl 4.0, aneb nikdo sám nevyhraje, p.42)

It can be seen on the Fig.8 picture the requirement for a complex process of operational planning and operative evidence and controlling. The importance of individual tasks depends on the structure of the individual enterprises. The basis of the system concept of operational production management is an integrated planning subsystem. The basic philosophy of operational planning is the willingness to plan realistically without creating backing reserves. It is necessary to ensure a link to strategic planning, opproval of possible variations among the departments of the company and applying the highest degree of flexibility.

Operational production management addresses the following key areas - what specifically, produce,plan, organize and control. It concerns:

- goals
- the way of management
- motivation
- forms of control
- organizational structure

Determining the planning and management conditions from the point of view of product characteristics and factors of production. It concerns:

- product and production program
- material supply
- workforce
- tools and set-outs
- machines and equipment

(Tomek, G., Vávrová, V., 2017, p.37,38)

Operationalization of goals within the value chain is focused on three areas:

1. Sales (share of sales, high quality/, increase in turnover, after-sales services)
2. Goals of the company (maintenance of machines, increase of productivity, saving of material)
3. Purchase (liquidation of dubious stocks, selection of suppliers, effective purchase)

3 ANALYSIS OF THE PRESENT STATE OF PROCESSES AND SYSTEMS

In this chapter the individual processes of the data and the information flows in custom engineering production at Matador Industries, a.s. Dubnica nad Váhom will be analyzed.

The company is focused on custom manufacturing in the field of general engineering, with the possibility of precise machining, welding, final assembly and surface treatment. The company is able to provide production according to the customer's documentation, but also according to its own development and engineering design of single-purpose machines.

The mission of the company is to shape in the world of mobility with a clear vision of being a respected and innovative provider of mobility solutions, meeting customer requirements according to global standards.

Key areas within the company values are:

Innovations and Change - Developing new technologies and innovative solutions to meet customer needs.

Trustworthiness and Reliability - Process consolidation is an advantage over the competition, building trust with the customers, business partners and vendors reflects in stable relationships and strenghtens the collaboration with them.

Purposefulness and Determination - is what makes it possible to achieve new horizons.

Collaboration and customer focus - strong relationships with the employees are very important.

Activity and agility - fast decision making and adaptation to the latest trends provide a competitive advantage for the company.

Positive thinking - building a team spirit, positive thinking is the key to increasing the value of society.

Defining priorities and dynamic portfolio management are the basis for implementing of the processes that correspond with expectations with the release of the necessary resources. Monitoring progress through KPIs and their digital monitoring. Support at all stages is the key to success in digital transformation.

Four steps approach for Matador´s Industry 4.0 digital transformation*:*

- *Understand digital drivers - Digital fields of play, Technology enabler*
- *Set digital direction- Roadmap Planning , Transformation Blocks*
- *Initiate and Execute - Stringent implementation of I4.0 projects and measures*
- *Steer the Digital Change - Clear Governance Structures*

(TSystem, internal document for Matador 2016_11_10_IN40@Matador_v03 Industrie 4.0 Digital Transformation)

After analyzing the information obtained in order to achieve MATADOR's goals in a sustainable and efficient way, it is essential for the transformation of production and logistics processes and their digitization to adopt a conceptual approach consisting of the following steps

- analysis of the affected processes of the company and proposal of their changes
- specification of functional requirements
- design of technical solutions in cooperation with specialized departments
- implementation of the solution

The company has a lot of strenghts. It´s the reason, why the company has perfect position in European market in automotive industry. Typical for the company is**:**

- Financial stability
- The power of the Matador brand
- Competency in the area of engineering & development
- Willingness to grow in new business areas
- Capability of fast decision making
- Following of ethics and social responsibility

- Unique product portfolio in the automotive industry
- Geographical location within CEE region

MATADOR Industries develops tradition of engineering and production with application of latest trends and innovations to achieve maximum customer satisfaction under the brand Matador.

The strengths of the company are:

- Strong value of Matador brand
- Experience in the production of structural parts
- Capability to produce oversized big tools
- Possibility to use the know how of the entire MATADOR Group
- VW Group standard knowledge
- Ability to show the quality of the tools
- Technological capabilities
- Stabilization of production after prototype phase

3.1 SWOT analysis

The strengths and weaknesses, opportunities and threats are identified by the SWOT analysis. SWOT analysis is a strategic analysis of the strengths and weaknesses of the company's opportunities and threats that will clarify the performance and prospects of the company. If the company develops strengths, minimizes weaknesses and threats, it will succeed. Within the company's internal and external environment, strengths and weaknesses focus on the internal environment and opportunities and threats to the external environment of the company.

Internal environment: company capacity, ways of financing, corporate culture, company brand. (www.fap.sk)

External environment: development, market trends, supplier - customer relations.

The SWOT analysis should be based on facts and not on feelings and must distinguish the current state and the theoretical possible optimal state.

At Matador Industries, a.s. the following elements of the SWOT analysis have been defined:

Strengths

- Professional and vertical markets (products and services)
- Components, business software, Industrial and professional service
- Robotics, automation, network equipment
- High class R&D
- Good infrastructure
- Size of EU market (~27% of world ICT market)
- Cooperation with Slovak Leader Industry 4.0 CEIT, SOVA Digital, Siemens Deutsche Telekom

Weaknesses

- Consumer markets, Internet and web products and services
- From components to applications, Data platforms' ownership
- Structural weaknesses
- No DSM yet (substantial impact on attractiveness to investment including VCs, BAs
- Lagging in investment in R&D

Opportunities

- To be a leader in automation of production process in Slovakia region
- Getting of new curstomers / orders
- Reduction of workforce in logistics
- Consulting expertise in I4.0 – service for future use
- Optimize production processes to minimize losses

Threats

- Cost of investment is too high
- Uninterest of personal
- Digital transformation (Data management and cybersecurity)
- Reliability in machine to machine communication
- Lack of adequate skill-sets to fully integrate Industry 4.0
- Sensitivity to the external conditions in labor turnover
- Less skilled labour

In regards with the proposed solution of the Master´s Thesis, the following factors of SWOT analysis are considered to be important: from the streghts are Robotics, automation, network equipment, cooperation with Slovak leaders of Industry 4.0, the weaknesses are Lagging in investment in R&D in the context of the automation of production process opportunities in the Slovak Republic region, the reduction of the workforce in logistics and the most serious perceived threats are too high cost of investment, sensitivity to the external conditions and high staff turnover. These factors of strengths and weaknesses, opportunities and threats influence all four tasks that are addressed in the work in order to confirm the hypotheses and fulfillment of the basic aim of the Master´s Thesis.

Focus and activities will be directed towards the following areas:

- increasing of production continuity in the defined stages
- integration of the proposed methods and elements
- training plan for the production and technological management
- setting the sustainability of the proposed steps
- automation of cost saving processes in the energy area

To achieve the goals it is necessary to define state of the art, design of implementation steps and implementation into practice.

3.2 Identification of data flows, their optimization and distribution in the production process

To verify the hypothesis that the dominant phase in the production process is the standardization of the data and information flow in connection with other business processes. The crucial company activity for fulfilling this task is the pre-production phase.

The role of the pre-production stages is to create the value generated in the design process.This value is judged by the customer. The pre-production stages in the company are carried out in the construction preparation of the production and technical preparation of production. The aim of the pre-production stages is the processing of the most effective solution in accordance with the technological and capacitive possibilities of the company.

The technical preparation of the production significantly influences the efficiency of the production and the product over a long period of time, either during the production of the single-purpose machine or in the case of repeated piece production in a different period of time. In the pre-production stage, it is crucial to determine the principles, procedures, type of machinery that will be for the given production the most effective and, last but not least, to determine the tools and jigs by which the product will be produced and controlled.

In the design preparation of the production, a future trend within Industry 4.0 is the paperless manufacturing, so the production documentation will be controlled digitally. The technological preparation of production is one of the most important phases of the pre-production stage, because it proposes semi-finished products for production, the sequence of individual operations, cutting conditions, the standard of time consumption, processing of CNC programs. The technological preparation is also responsible for the change management that is very challenging in terms of the discipline and compliance with internal rules. This is due to the frequent changes from the side of the customer, which accur in the piece production. (Kováč, J., 2017)

This part deals with the analysis and the next part of the thesis will address the issue of the areas of the pre-production stages:

- Technological procedures and the standards of time consumption
- 3 D measurement and simulation in the creation of measuring programs
- Design preparation of production - connection of BOM with ERP

3.2.1 Creation of technological procedures focused on Content and Time Effectiveness

The area of technological process generation is one of the key areas in terms of increasing labor productivity in manufacturing.

Technological preparation of production in the pre-production stage proposes optimal semi-finished products for production, the sequence of individual operations for the conversion of a semi-product to a product with the aim of ensuring production at minimum costs and achieving high labor productivity, cutting conditions, the standard of time consumption, CNC program processing.

From the point of view of production efficiency, it is important to consider the introduction of a new software system to standardize the individual activities, where the work result will be real times of unit and preparatory work. The implementation and use of the software will ensure the sustainability of making the production time real.

In order to achieve an increase in labor productivity, it was necessary to analyze the current state of work consumption standardization, analyze the results and describe them. After training the staff for the new system, a unified methodology of standardization will be needed.

The analysis showed the measurement of deviations for some types of technological processes, unified methodology was not established and the calculations were subjective in many cases. In the assembly and the welding area, it is necessary to consider the need for teamwork when installing the parts into the weldment, welding and assembling of the manufactured products.

3.2.2 Bundling of BOM with ERP

Because the company is a project-oriented company that provides complex deliveries to its customers in the field of general engineering and industrial automation, a weakness was defined to be the interconnection of the bills of material (BOMs) in Inventory with ERP. The designer when creating the drawing documentation adds information about the models to the ability of individual parts to display this information in the production drawings of the individual parts / items.

This same information goes to TPV 2000, which generates the numbering of drawings of produced items. The models are renamed according to the assigned numbers and drawing documentation is created. Assembly drawings do not contain BOMs. The proposed solution will require the correct filling of the properties of the individual 3D models, which will be the holder of all the information in the TPV 2000. The new solution system would include several tools for their input or generating by Autodesk Inventor.

3.2.3 Capacity planning

Planning and management with incorrect data are among the shortcomings of current productions. From the point of view of capacity utilization it is necessary to monitor the capacity utilization of production, especially of the individual CNC machines, in order to be able to react in time to the processing of programs for machines, which are available in terms of capacities.

In the planning area, the process of prioritizing orders is unclear, there is no fixation of the production plan and there are no clear rules for the case of the plan disruption. Reporting and tracking of planning efficiency are not sufficient. Norms are not accurate and used to plan all activities.

It is proposed to process the capacity forecast from the existing orders, the orders that are in the pre-production stages and real contracts. Fulfillment of the production plan is not evaluated sufficiently. Reporting monitoring of employee performance indicators on a monthly basis is important for the development of KPI for management decision making.

The capacities of CNC machines are calculated through the man-hours, not through the machine hours. The bottlenecks in production are not caused by insufficient equipment capacity, but by a lack of human capacity.

From the point of view of the operational management of production, it is necessary to monitor the capacity utilization for 14 days in order to be able to take measures to eliminate skidding in a timely manner. Visualization as a tool of Industry 4.0 will also be a part of the adherence of production deadlines. Material flow mainly between material division and welding area is not set efficiently. It will be necessary to set the zoning and make a better orientation in the welding area to eliminate the downtime.

Capacity planning as one of the management tools is to create the conditions for the realization and control of the set goals. The planning process puts pressure on the management to timely take action and monitor risks in terms of keeping the delivery dates.

From the point of view of the need for capacity utilization in custom production, where they are normally unevenly used, it will be necessary to monitor the capacity utilization of the individual centers in monthly and quarterly advance.

Monitoring of the maximum machine capacity, human capacity and labor productivity is one of the KPIs, which are important to meet the expected goals.

Month	Production center	Profession	Name	Capacity of machine	Human capacity	Attendance	Paid hours	Downtime	Work Productivity	Utilization of human capacity	Utilization of machine capacity

Table 2 - Tracking capacitive indicators of CNC machines

The table (Table 2) shows the design for monitoring of CNC machine indicators on a monthly basis. This report will serve to take measures for optimal use of CNC machines in order to achieve maximum efficiency.

3.2.4 Tracking costs of orders

Within the project management, there is insufficient ongoing monitoring of project costs on the indicators such as material costs, Nh consumption, technological cooperations and transportation costs. This affects the timely suggestion of measures during the project for profitability and keeping the delivery dates and customer-required quality of products. In the framework of implementation, a proposal will be presented for reporting monitoring of the cost of individual projects during the time of the order execution.

3.2.5 Employee training and incentive system within self-control

Quality of production has an irreplaceable role in the process because it can not be separated from the requirements for customer satisfaction, but it is not sufficient to keep the customer. As a weakness of the company, in regards with the quantity of non-conforming products, was identified the self-control by the production workers. Repeatedly, the non-conforming products are identified in the inter-operational or exit.

The current situation has shown us the following problems:

- Insufficient motivation of employees to perform self-control

- Continuation of the next operation on a non-conforming product, thus increasing the cost of report counting about a non-conforming product
- Increasing the number of non-conforming products
- High costs of non-conforming products

A solution is proposed to create a quality tool: The Quality League as a part of the visualization of the monitored suspended parts in the production together with the time period until they have been solved.

3.2.6 Energy cost optimization with Industry 4.0 support

From the point of view of monitoring of the KPI indicators, energy consumption, its measurements, cost monitoring and timely taking measures to eliminate costs are also very important. At present, energy consumption is not monitored in the company within the hourly, ¼ hourly and monthly consumption with the oversight of costs overrun. Within the implementation, a proposal for automated reading of energy consumption / electricity, gas / for cost saving purposes will be processed.

3.3 Standardization and alignment of programs for the management of CNC machines at individual workplaces

To fulfill the task of standardization and alignment of programs for CNC machine management at individual workplaces, it will be dealt with optimization of CNC programming. For CNC programming in the first phase, it will be necessary to add the tools and preparations to the database.

To streamline the production and shorten the production times, it is important to address the standardization of the technological procedures for technologically similar products. The starting point will be machining on CNC machines.

Under the conditions of the development of Information Technology and Industry 4.0, the technological standardization is one of the factors that affect the efficiency of TPV at the following:

- processing of technological procedures

- generation of CNC programs for machines with prescribed tools, parameters and the way of clamping

Programs are used to determine the appropriate tools, equipment, sequence of operations and processing conditions. It is very important to know the input data for creating data and as a part of the complex basis of technological procedures of the company.

3.3.1 Optimization of CNC programming

The optimization of CNC programming in piece production companies is of great importance nowadays. The CNC program can flexibly respond to the changes in production. In the company there are used Heidenhain programming systems (90%), Fanuc (10%), Sinumerik (10%). CAD / CAM systems allow you to create a VNC program for variously sophisticated and precision demanding products. Within the area of the creation of CNC machine programs the proposal is to introduce optimization of CNC machining and 3D simulation by introducing VERICAT, a simulation software, which has the advantages that will be presented in the imlementation part of this thesis. To implement the proposed optimization, it is necessary to realize:

- 3D models of CNC machines
- Filling the software database TOOLs Managment with ERP connection
- New VERICUT simulation software

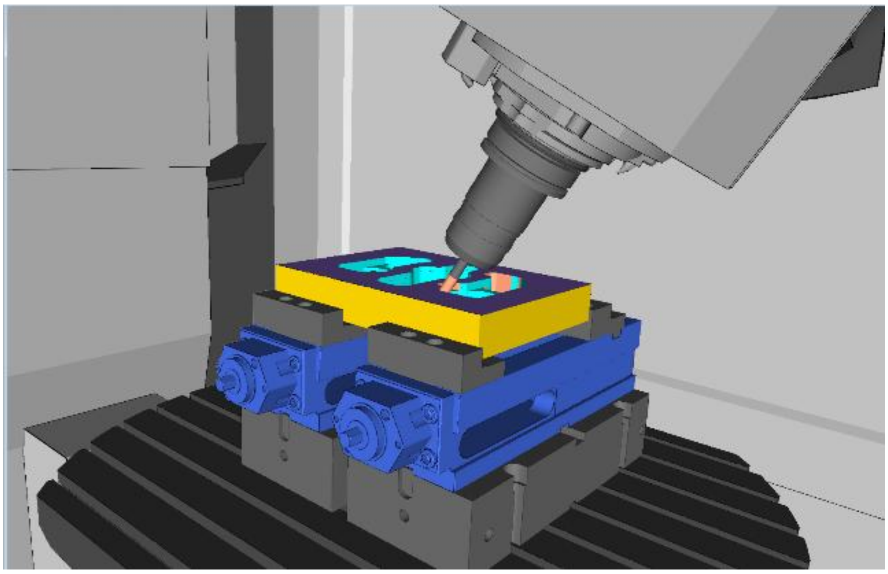

Fig.9 - SW Vericut

http://www.cgtech.com/

In the (Fig. 9) an example of machining with SW Vericut can be seen.

3.3.2 Elimination of losses on CNC machines

In the analysis of losses on CNC machines, several types of losses were identified. In contract production, the losses on CNC machines are caused by several factors. Two types of key losses were identified:

As the first type is the losses caused by *motion*:

When analyzing and performing observations from the point of view of motion, the identified weaknesses were: a need for passage elimination, elimination of search, the necessity to clarify the production, the need to introduce standards for production preparation and storage on CNC machines and to make working conditions more efficient.

As a second type, losses called as *unnecessary processes* were identified.

These include downtime caused by the long time of tool clamping, machine setting, program editing, especially when manufacturing welded products. The solution will affect not only the productivity but also the quality of the production. There is willingness to solve the listed type of loss in a new way of setting and measuring on a CNC machine using 3D - touch probes. Machine setting can be carried out more quickly, in easier way and accurately using the HEIDENHAIN 3D Touch Probe.

In addition to the sensing functions when setting the machine in manual mode, a range of measuring cycles is available in the programming modes:

- Measuring cycles for detecting and compensating for oblique workpiece position
- Measuring cycles for automatic starting point setting
- Measuring cycles for automatic workpiece precision with tolerance comparison

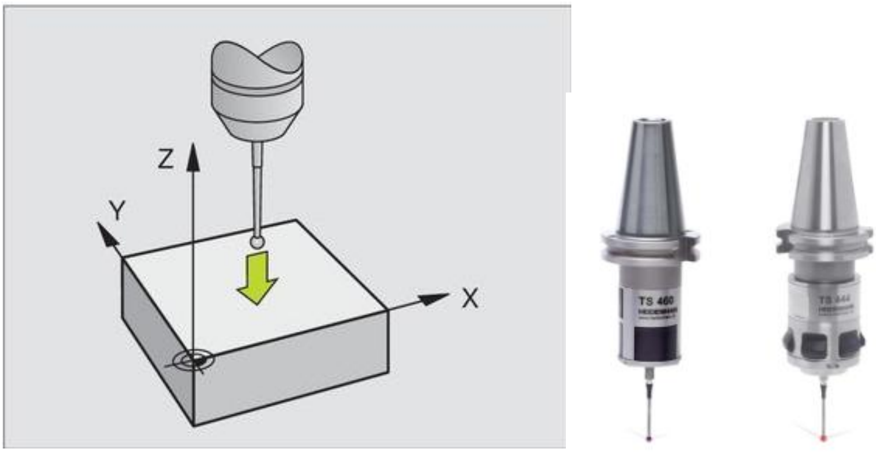

Fig.10- 3D measuring touch probe

(http://www.tormach.com/blog/wp-content/uploads/2015/07/31858-)

The advantage of using 3 D touch probes (Fig.10) is mainly the reliable measurement for different types and sizes of tools and accurate measurement even in the cooling emulsion. The probe can be used to prevent damages in the event of tool damage or destruction.

3.4 Summary of statistical reports on individual workplaces of CNC machines for evaluating the performance and quality of the production process

The statistical overview and performance of individual CNC machines, their evaluation, the monitoring of OEE indicators, the use of their capacities in continuous mode, autonomous maintenance are important areas for confirming the proposed hypotheses.

3.4.1 Efficiency, qualifications and training of human potential

Production is a major part of the chain and represents production to meet customer needs. In the manufacturing process, there are areas to implement the goals of increasing labor productivity. Custom production is the most flexible production method with the possibility of correcting errors in the production process, so that the company will not suffer great losses.

In order to ensure the required quality from the customers, the company of high-skilled employees and the demanding of the equipment of individual CNC machines, efficient use of working time, autonomous maintenance, OEE and internal logistics are discussed in the following parts where there is a need to implement field designs using Industry 4.0 elements.

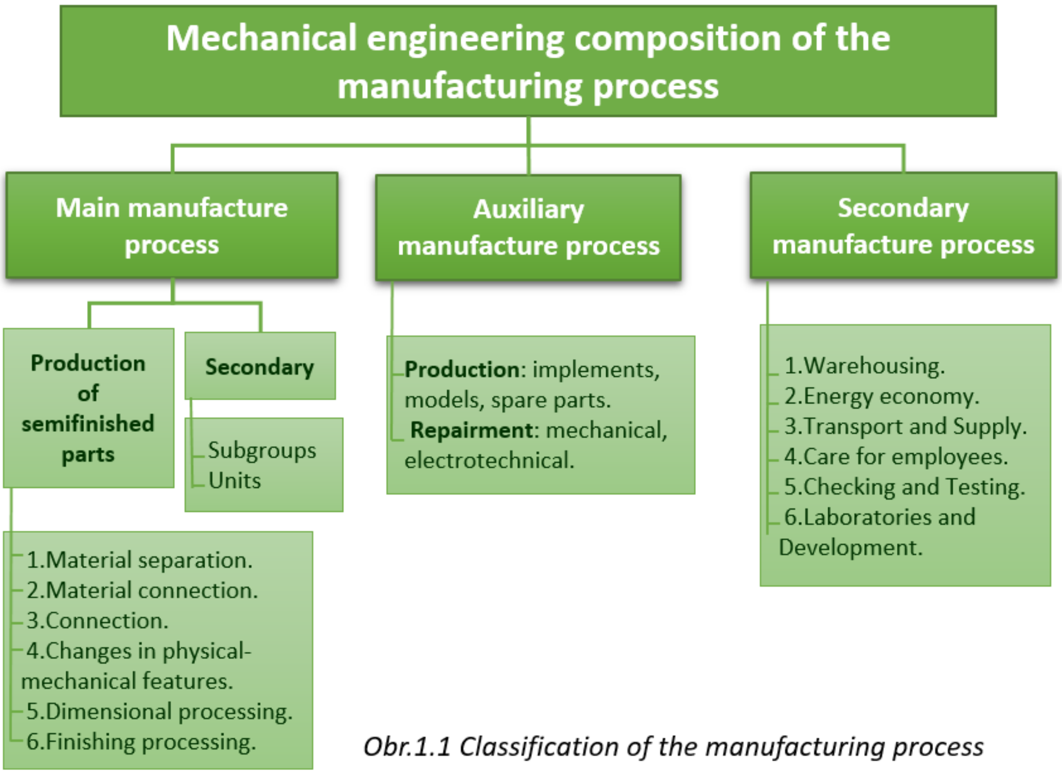

Fig.11 - Classification of the manufacturing process

(Source http://www.sjf.tuke.sk/seminsky/IVS/PVPaS.pdf)

As shown in the Fig.11, the main, auxiliary and secondary processes are distinguished in production. The principles of rationality of the production process are:

- parallelism (operations and processes are performed concurrently)
- continuity (the following operations of the same process are to be performed immediately after the end of the previous operation)
- synchronization of the operations of the manufacturing process,
- minimal path of movement of manufacturing objects in production
- rhythm (all operations and production process are performed at specified time intervals)
- high degree of automation and flexibility

In order to ensure sufficient qualified personnel on CNC machines, it will be necessary to implement an internal system of retraining of production workers with the possibility of multiprofession or more machine service.

3.4.2 Adherence to 5S Policy of Autonomic Maintenance Plans and Procedures

Autonomous maintenance as a way of involving machine and equipment operators into everyday maintenance is a very important part of evaluating the performance and quality of the production process. It is one of 5 TPM programs. Autonomous maintenance is intended to prevent deterioration of the production facility by day-to-day over-control, it enables to better understand the operation of the device.

For its implementation, it is necessary to define standards for cleaning, lubrication and regular inspection of the equipment. In order to comply with the Autonomous Maintenance plans and procedures, it is necessary to set the motivation of the individual teams to work together and to set the responsibilities of all members in fulfilling the assigned tasks and achieving the objectives. The league of teamwork as a motivation of the production employees helps us to meet the goals of minimizing downtime and higher work performance.

3.4.3 Efficiency of the use of the workforce fund - work through breaks on key CNC machines

In the company, the identified problem is the overloading of CNC machines and associated threats to delivery dates for customers, the low OEE and the need for capacity cooperation that causes a deterioration in contract profitability for the company. In the framework of the analysis, a proposal of activities has been prepared to increase the efficiency of the use of the workforce fund on CNC machines The proposal of steps is as follows:

- retraining selected employees so that they can take over the work on machines even during breaks
- processing of the reporting to monitor work during breaks, ensuring the continuous and uninterrupted operation of the CNC machine and the relevant master is responsible for its correctness
- each machine will have a visualized, specific turn-off procedure for a crisis situation

Impact on the increase in productivity:

- Work on key CNC machines even during breaks - there is no need to turn off the machines
- Increasing production continuity

3.4.4 Efficient use of OEE-overall equipment effectiveness

OVERALL EQUIPMENT EFFECTIVENESS-OEE is a key indicator for businesses that are active in continually improving the production and trying to reach lean production. It is used in programs such as Downtime Management (DTM), lean manufacturing, Six Sigma or Kaizen. The overall efficiency of the OEE device reveals the hidden capacities of the production machines that can be used by the production teams to achieve an increase in operating profit.

OEE is the most widely used KPI key performance indicator for evaluating of the production efficiency. The OEE value is expressed as percentage of the utilization of the standard capacity of the machine (machines and lines). An OEE value of more than 85% usually shows an excellent use of the device, that means the device produces efficiently and effectively. In some sectors, such as continuous production, the OEE value is close to 100%, but in others, such as piece production, it often tends to be much less due to downtime between individual operations.

OEE has a direct impact on business performance of the company, on the cost, output and profit. OEE is therefore a very important indicator for management that, in its on-going evaluation, can positively influence the results of the production enterprise. If managers have ongoing results in OEE indicators, the theory shows how it is possible to improve production and increase the efficiency of the production process.

1. Producing more products is possible by, for example:
   - reducing downtime, it means better use of production time
   - increasing the machine cycle - by modernizing the equipment in technology, mechanics or automation
   - increasing the permeability – transit of the product through a manufacturing process, e.g. process optimization
2. Improve tha ratio of matching (non -matching products) for example:
   - reducing the number of non-conforming products
   - improving the quality of the production facility – e.g. modernization of equipment in technology, mechanics or automation by improving production technology

For decision making and production optimization, managers need a solution that can be easily inserted and provides information both in real-time and in terms of evaluating the elapsed time period. A suitable solution is (precise and, most importantly, the least dependent on human factor) detection of the actual results of production over time. The independent automated data collection and production monitoring is therefore a necessary prerequisite for realistic evaluation of production efficiency.

An important part of the solution is also the awareness of the entire production team, including operators and workers. In practice, the solution of providing information directly into the production process has been successful in ensuring that people are immediately informed of the results of their work. This awareness is the first and self-acting factor for improving production, the efficiency of which can be significantly increased by the financial motivation of the production team.

It is necessary to have such an organization of the production process where data are collected automatically and provide information in the form of production statistics and OEE in real time. Everything can be done without operator intervention or by partial utilization of human factor input to the needs of the given production.
The total efficiency of the device is calculated as a product of three factors according to the formula:

OEE = Device availability * Plant performance * Production quality * 100 [%]

The factors:

- equipment availability is the ratio between actual production time downgraded by unplanned downtime and planned production time
- the performance of the device is the ratio between the actual quantity of products produced and the standard quantity of products, the actual performance of the device being usually lower than the standard capacity of the device
- Quality of production is the ratio between the quantity of identical products and the quantity of products produced, the quantity of identical products being usually less than that produced by the quantity of non-identical products

The scheme of these relationships is illustrated in the following figure (Fig 12)

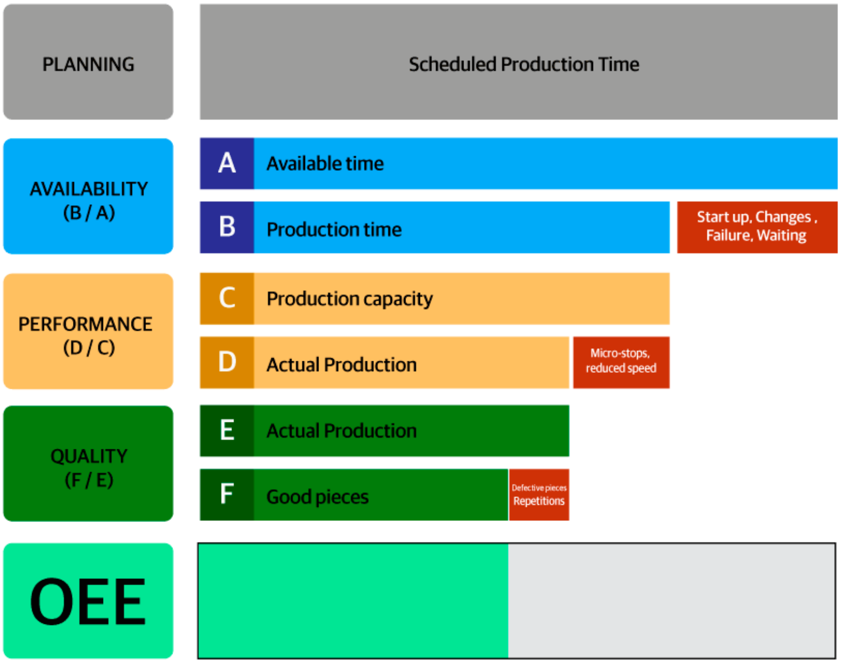

Fig.12 - Diagram of calculation of total machine efficiency

(Source http://www.sistemasoee.com/en/oee/89-for-dummies/108-calculate-oee)

By the objective measurement of the individual factors, it is possible to obtain the values to calculate the products of, and get „overall device efficiency – OEE“. This way, it is possible to evaluate the utilization of the device and possibly look for ways to increase it.

In the company, by implementing the OEE, the intention is to increase the effectiveness of the production equipment online by monitoring the key parameters. As layers of solution are data collection from machines, processing and evaluation of data and display panels.

The analyses themselves and setting of OEE on CNC machines will be necessarily done in 2 stages:

- In the first stage the training of the employees and implementation of solutions in order to achieve 60% availability and runtime at 55%
- Verification and implementation of new solutions in the second stage - availability: 70%; runtime 60%.

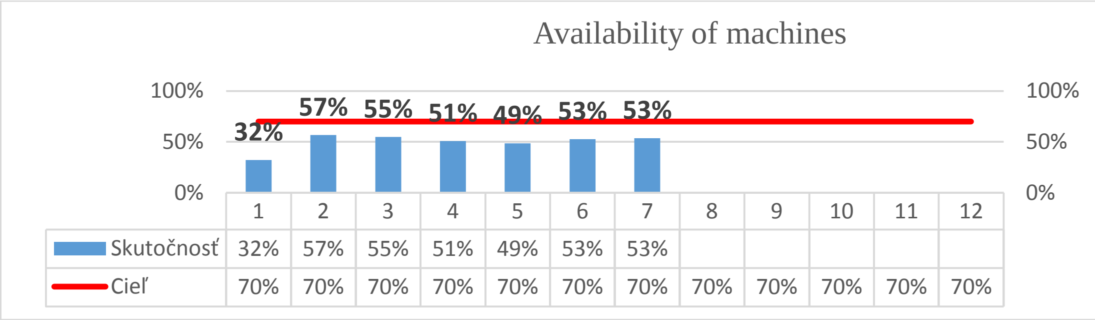

Fig.13 - Avalibility of machines

(Source Internal document)

As can be seen from the graph (Fig.13), the availability of machines in the first 7 months is significantly below the planned target. The steps and measures proposed in the work aim to reach the end of 2017 at the level of availability of CNC machines 70%. The current state of availability of the machines can be seen on (Table 3).

CNC machines	2017	1.	2	3	4	5	6	7
FUQ 125	63%	42%	74%	67%	73%	62%	60%	67%
VLC 2500	45%	39%	61%	58%	39%	38%	44%	36%
Mecof Dynamill	47%	43%	57%	55%	40%	43%	46%	44%
Area FPT	61%	44%	69%	65%	54%	64%	64%	69%
SKQ12CNC	51%	12%	71%	34%	35%	68%	68%	73%
SKIQ16 CNC	55%	32%	61%	47%	54%	57%	64%	69%
SKJ20 CNC	23%	31%	55%	46%	18%	13%	0%	0%
FFQ100 CNC	48%	45%	47%	48%	56%	38%	51%	53%
WHN9B CNC	56%	29%	63%	62%	41%	61%	56%	78%
WH10 CNC 10	21%	17%	11%	18%	29%	22%	31%	20%
WHN10 CNC 14	62%	27%	64%	69%	68%	56%	70%	78%
FSQ125 ORA3	60%	27%	73%	65%	56%	70%	70%	63%
PUMA2000Y	37%	20%	56%	59%	38%	24%	27%	32%
PUMA4000XLMB	31%	9%	45%	42%	35%	25%	37%	23%
WXD 100	48%	26%	53%	44%	64%	53%	19%	74%
MCV 100 VA	59%	42%	55%	67%	64%	69%	73%	47%
DepoSpeed 1011	55%	42%	69%	66%	49%	57%	52%	50%
DMU 60P	60%	25%	62%	72%	72%	48%	79%	65%
WHN 13	49%	35%	43%	59%	58%	48%	53%	46%
WH10 CNC 13	39%	19%	51%	34%	35%	32%	46%	56%
WXH 100	45%	27%	39%	47%	43%	39%	55%	67%
WHQ 13	53%	39%	66%	59%	55%	47%	53%	49%
DMU40	64%	47%	56%	66%	67%	72%	75%	66%
DMF260	64%	51%	58%	67%	75%	66%	69%	61%
Reality	**50%**	**32%**	**57%**	**55%**	**51%**	**49%**	**53%**	**53%**

Table 3 - Current availability of machines

(Source Internal document)

Downtime	**Duration (min)**	**Part (%)**
Downtime of personal occupation	20328	81,76
Clamping and Unfastening	1974,18	7,94
Machine Setup	1450	5,83
Machine Setup	414,97	1,67
Break	225,95	0,91
Implements	139,42	0,56
Component Measurement	133,48	0,54
Issuance	94,3	0,38
Cleaning machine and workpiece	60,83	0,24
Defect/Machine Maintenance	15,72	0,06
Personal reasons	10,05	0,04
Design system	8,1	0,03
Upload work change	4,98	0,02
Break	2,2	0,01
Unfastening	0,45	0
Total	**24862,63**	**99,99**

Table 4 - Overview of 1 CNC machine lags

In the table (Tab.4), the average time of the machine downtime according to the defined types is seen. This is absolutely the first step on the way to process intelligence when having a preview of processes.

In the Fig.14 is summary weekly report OEE CNC machines

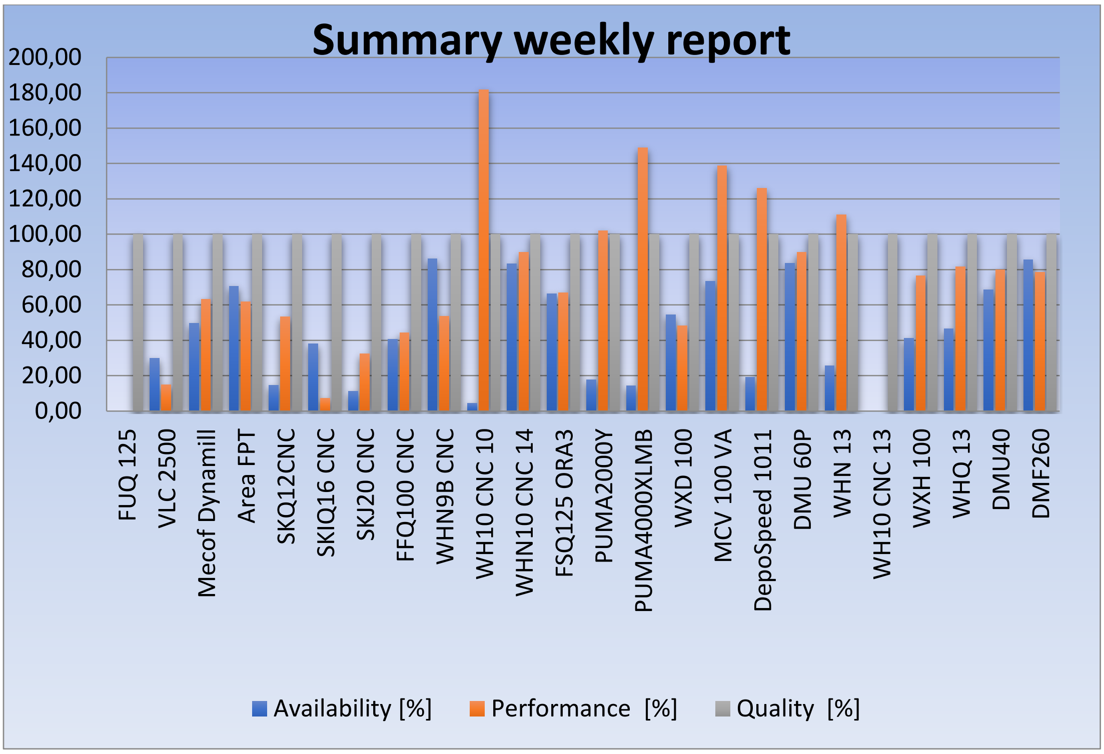

Fig.14 - Summary weekly report OEE

3.4.5 Introduction of SMED studies on selected machines

The SMED method is an analytical approach to defining, simplifying, and shortening the time required for a transition in production (in our case, the process of dismantling and clamping of the piece that is being produced).

The result of the correctly implemented SMED method is the increase in productivity and continuity in production (time for machines needed to produce the product) SMED is also used for:

- Increase production flexibility
- Reduce delivery time, or total production time of the piece

Goal of SMED Method:

- A transition in production made with a minimum of internal steps that allows a process with minimal downtime
- Reduce the time needed to transition
- Reduce the cost and effort needed to make the transition

- Reduce the number of tools used during the transition
- Reduce the number of transitions
- Reduce the number of transition steps
- Strengthen team approach

The SMED method divides activities during the transition to 2 categories:

- **Internal activities** - those that can only be done on stopped machines
- **External activities** - those that can be done even when the machine is working

Steps of SMED:

1. Measurement of the process - transition - activities (placing the piece on the machine, solving of the technological problems with the programmer, precise positioning of the product)
2. Specification of the internal and external steps
3. Execution of external activities before switching off the machine, or just after it is switched on
4. Short cut of the internal activities / assistance of the service activities
5. Short cut of external activities / preparation of the tools before the beginning of the production, preparation of measuring instruments, control of the program, study of the documentation
6. Standardization of transition procedures / clamping and unfastening process, standardization of tools and measuring instruments, substitution matrix

3.4.6 Replacement matrix and multi - profession in production

The identifying of bottlenecks showed a problem that the part of the workers were retrained only for one machine or activity without the option for flexibility of production. In this context, activities are proposed to reach the desired goals of the work.

Proposal of activities:

- Map the state of the multiprofessional skills and opportunities for the training of individual employees

- Create a substitution matrix
- Identify the employees who will be retrained
- Retrain the selected staff for new positions
- Use and move employees to work at more workplaces within one day
- Process the training plans for individual employees
- Determine mentors

Impact on productivity increase:

- Higher worker flexibility and shorter continuous production time
- Reduction of capacity cooperation
- While capacity fluctuations, less need for agency staff

3.4.7 Presentation layer - Visualization

In order to display the monitored data and present the status, results and reports for the company, it is suggested to perform the visualization on the monitors in the production premises. A problem, identified here is a lack of employee awareness of the key production indicators that have an impact on productivity increase in production, on the production quality, and compliance with customer-required delivery dates.

As a part of the solution, the following activities are proposed:

- Installation of monitors into production facilities
- Design of reporting types and their processing for visualization
- Updating of defined reports on an online basis

Goal of visualization:

- Visualization of plans
- Continuous employee awareness will enable them to focus on performance and achieve the goals that will be set for them more easily
- Performance visualization will help to increase the quality on production sites, keeping daily plans, automatic monitoring to increase productivity in the range of 3-6%

- The goal of visualization is to remove the administration load from masters
- They will get more time to work, the most advanced control of worker productivity in online mode, and accurate and credible material for analysis will be obtained .
- The main benefit of visualization is that it supplies the users with the accurate, reliable and undistorted information about the state of use of specific production facilities
- All departments in the company must be involved in visualization to optimize the whole process

Visualization is intended for presentation on monitors in individual parts of production areas. The content will be displayed with defined display frequency and display and refresh of the time. Various monitors will be able to visualize different content. It is suggested to display the state of production, machines, and planning to increase performance in production. Integration of ERP with a presentation layer for online item tracking is one of the key indicators.

Proposal of reporting for visualization:

- OEE - current status of CNC machines in the given shift
- OEE - availability - bar chart on machine availability
- OEE - monthly reporting for the previous month
- Plan Fulfillment of standard hours
- Interim status of project fulfillment in the current month
- Skid items in the production centres available more than 5 days
- Blocked products - suspended parts because of the quality
- Teamwork League - Current Assessment, Improvement Movement
- Report of the material being uploaded to the assembly

3.5 Use of smart technology for the internal tracking of material in welding area

Production and manufacturing mean to have a central role in the structure of each customer-oriented company. The typical deficiencies of custom production is

high production-in-progress, warehouse stock, inefficient handling activities, long lead times, inefficient use of production areas. The amount of unnecessary tasks people have to carry out do not add value to products and profit creation. Missing components into final units despite high inventory, unbalanced material flows cause a bottleneck in the manufacturing process. The main objectives in production are: profitability, productivity, efficiency, performance, adaptability, responsiveness, quality and continuous improvement of products and services throughout their entire life cycle.
Source (http://www.sjf.tuke.sk/seminsky/IVS/PVPaS.pdf)

Production facilities are divided into 3 groups:

- Manufacturing equipment - machines and facilities
- Handling equipment
- Control devices

3.5.1 Material Flow – Zonation

In a contracted engineering company, the cost of material handling accounts for up to 20% of production costs. Organized material flow in production is particularly important because of the following reasons:

- there is a potential for reducing internal costs in the range of 10-15% of the cost of the product)
- clarity of the layout of the material in terms of spatial areas
- loss times prior to the beginning of product manufacturing
- excessive handling by workers
- transport and handling are important factors of continuous production time

For the individual production centers, it is necessary to carry out the zoning of the individual zones according to the principles of industrial engineering. In the work, the following activities are suggested:

- designation of entry and exit zones
- definition of a new workplace for assembling work orders for the medical industry

- new marking and zoning of entry, exit and transit zones
- change of material flow arrangement of a small machine shop

Impact on productivity increase: simplification of material transfers and visualization of this material not only for service activities, but also for masters, dispatchers, control staff and the operators => faster material transfers have a direct impact on increasing of production continuity.

3.5.2 Tracking of dense material in welding area

In order to carry out the manufacturing operation, the product must be placed at the identified location and especially the welding area, where there is supply of material from all production centers, is a key production center for this company to optimize material flow. When analyzing material flow, a problem has been defined, that will be addressed by a proposal of smart solution for material picking. A problem in the welding area has been identified:

- insufficient coordination of staff while taking material from individual workplaces of the company
- lengthy deployment of material for production workers
- low productivity in welding area

The goal of increasing the productivity in the welding area and increasing the permeability is:

- tracking of online items in production by collecting data / ERP
- material flow in the welding area and determining the location of small parts and separate large items
- assigning a person to import items into the welding area

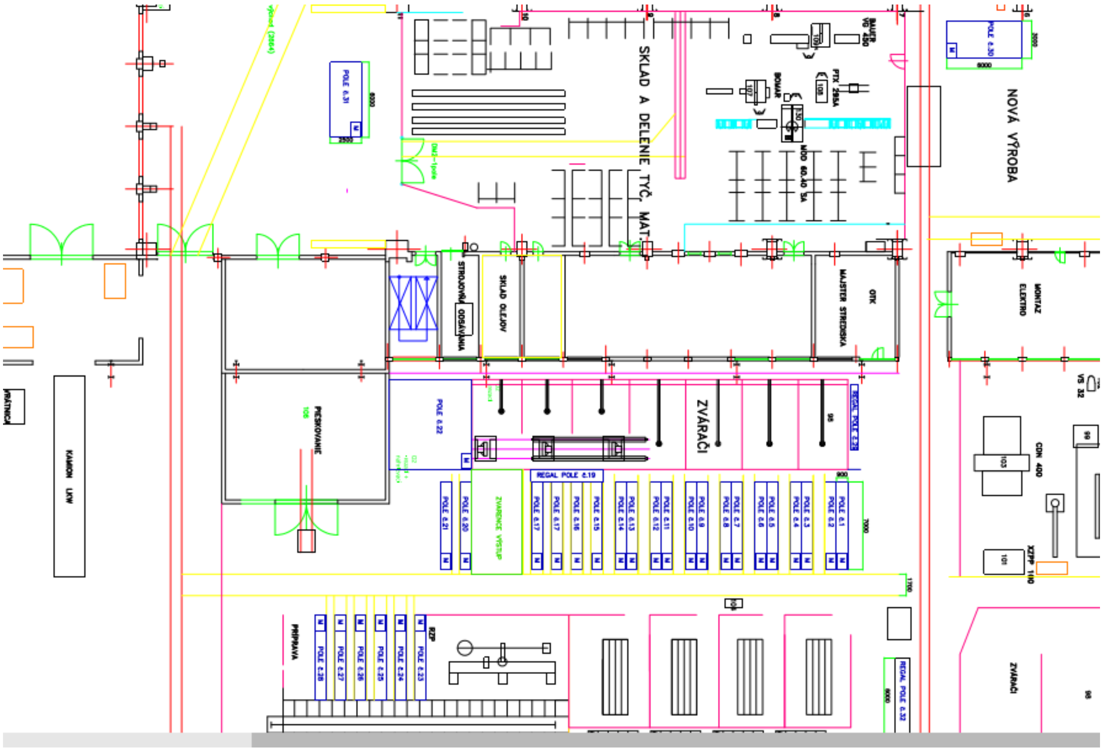

Fig.15 - Design of zoning of the welding area after introducing code readers (Source Internal document)

Design of welding area zoning and welding area logistics process as shown in the Fig.15 according to the proposed procedure:

The responsible worker will receive the information about the import of the material to the production center - the welding area, after taking over the material, he will ensure the code is read from technological procedure of so- called production order of the weldment. Consequently the worker ensures that the part is loaded into the weldment by scanning the barcodes from the stands (marked in the fig. by blue colour) in the given zone. After the storing of the material the worker prepares the material for production workers according to the material from ERP. Within the implementation, a processed list of available parts will be also visualized on the monitor. The welding area worker will carry out removal of material by code readers and scanning the codes of technological procedures in the given zone.

4 IMPLEMENTATION OF INDIVIDUAL MODELS WITH INDUSTRY 4.0 SUPPORT

From the analysis of the current state and processes, the design and implementation of individual models was elaborated. After assessing the current situation, it is possible to identify potential areas to achieve the proposed benefit.

4.1 Data flow in the production process

As a part of the implementation of the proposals in the field of pre-production stages, a suggestion is to implement a software for standardizing the work of individual operations, which would make the production times of individual operations real. In the field of Tool Management, the primary goal is to reduce the cost of Tool Management.

The proposed suggestions for the steps are:

- reducing the number of tools used
- optimizing inventory of tools and implements
- increasing the productivity in CNC programming
- increasing the productivity in setting of the tools
- shortening of the setting times = increasing the labor productivity

The individual steps will be performed in the following stages:
The cost of processing the database would represent the investment of 60,000 €
Investment Costs of defining the used tools and implements in the database from the standard used in the company 30,000 €
Establishment of stock records of tools 25,000 €
Connection with the ERP system of the company 20 000 €

Year	1	2	3	4	5
Effective saving	35 672	95 189	126 111	154 611	154 611
Effective saving total	**35 672**	**130 861**	**256 972**	**411 583**	**566 194**
Hardware	7 000		10 000		
Software	84 890	10 275	65 575	16 029	16 029
Pers. and invest.costs	123 890	26 275	90 975	30 429	30 429
Total cost	**123 890**	**150 165**	**241 140**	**271 560**	**301 998**
Yearly Balance	(88 218)	68 914	35 136	124 182	124 182
Cumulative balance	(88 218)	19 304	15 832	140 014	264 196

Table 5 - Total cost vs. Saving cost in Euros

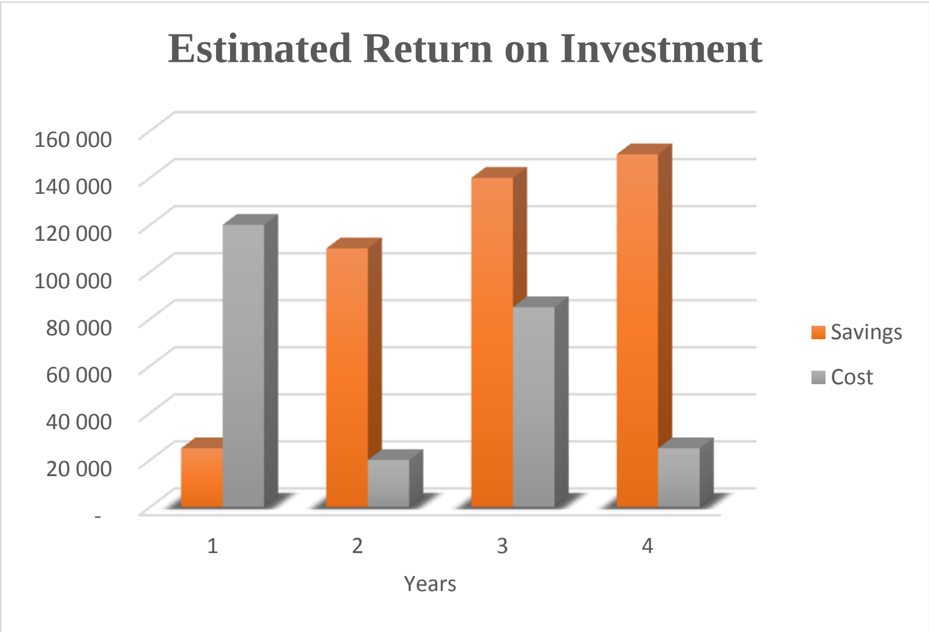

Fig.16 - Estimated Return on Investment

(Source internal document)

When analyzing the chart above, it is possible to see that the positive return on the investment in the cumulative for TPV and NC programming and production is expected in 26 months from the introduction of the investment (Fig.16)

Of the total planned savings of 154,611 €, TPV and programming savings are expected to be 59,611 € and 95,000 € in production.

4.1.1 Proposal for the solution of the connection of the design bills of material with the ERP system

The solution proposal can be divided into three parts in terms of process:

a) The standardization of the content of the models and the information added to the 3D models – the aim is to attach as much information as possible to the model. The information will automatically be passed into the BOM on the assembly drawing and into the corner stamp on the production drawing and into the ERP.

b) Adjustment of purchased standard components of material availability - frequently used standardized parts.

c) Programming of new tools for mutual communication between the Inventor and the ERP - the proposal is based on the extension of the ERP program to a new module.

d) The advantage of this solution is to remove the manual rewriting of information into the ERP, manual operations will be automated and errors that have arisen during the manual process will be eliminated.

The designers can devote time to the development and design process.

4.1.2 Capacity UtilizationTracking Proposal

Sources of production capacity are determined according to the following indicators:

- type of production equipment (profession, type of machinery according to technical parameters)

- number of production facilities
- usable time fund of equipment
- human capacity

The production capacity is determined by the production schedule and by the norm of the time required to execute it.

The effective time fund of the production machine is calculated according to the formula:

Tef = p . h . (1 - t pr / 100) **(**h)

where: Tef - annual effective time fund of the machine

p - number of working days in the year,

h - number of working hours in l day

t pr - planned downtime in percent from the nominal time fund.

The design of capacity utilization tracking will include two areas:

- Monitoring of capacity utilization for the contracted projects
- Monitoring of capacity utilization, including the perspective of expected new projects.While manufacturing technologically similar projects, the so called representatives of the products are taken into consideration

Capacity overhead view of production		September	October	November
MC	**Profession**	**%**	**Vyť. v %**	**Vyť. v %**
22071	**Turning machine**	85,16	20,10	22,39
22072	**Milling machine**	80,79	35,33	40,76
22073	**Grinder**	30,16	21,56	27,20
22082	**Boring mill CNC**	124,23	121,23	117,22
22083	**Small CNC machnine**	57,52	21,06	32,33
22085	**Big CNC machine**	128,52	102,19	92,61
22094	**Portal mills**	91,10	62,46	98,10
22111	**Small horizontal machine**	34,94	30,03	39,23
22121	**Big horizontal machine**	89,63	53,08	61,82
22135	**Welding**	95,96	62,97	60,45
22136	**Sand blasting**	117,87	115,76	68,37
22202	**Assembly**	54,83	64,87	81,18
22212	**Elektro assembly**	13,01	35,64	106,47
22214	**Painting**	103,79	88,80	98,85
22215	**Sheet metal**	131,06	82,34	76,99
P1	**Machining professsions**	80,41	52,65	57,66
P2	**Handling professsions**	73,40	65,93	78,27
SUM	**Production**	**76,63**	**59,71**	**68,54**

Table 6 - Capacity overhead view of production

(Source Internal document)

In the Table 6 the Quarterly Capacity Utilization Tracking Table in individual months can be seen. The expected projects are already included, but they are not technologically released into production. This table is intended for all departments of the company in order to be able to take timely measures for the entire utilization of the capacities of individual centers or to fill their free capacities. There are 200 employees working in the production. They are equally distributed at machinning professions and handling professions.

As a part of the follow-up of the weekly production plan with the aim of producing items according to the daily plans, tracking the reporting of skid items through visualization monitors is suggested. Fulfillment of the daily production plan will secure the keeping of the customer required terms and it will enable us to timely take measures either through overtime work or by use of external capacity resources.

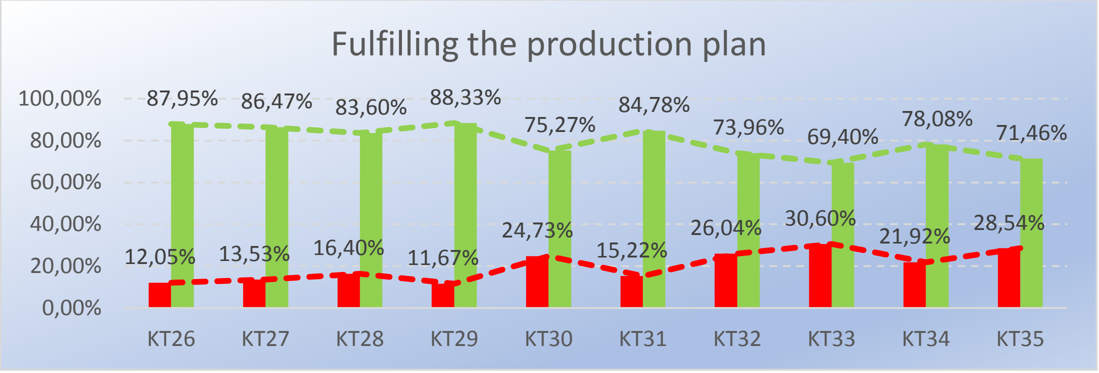

Fig.17 - Fulfilling the production plan

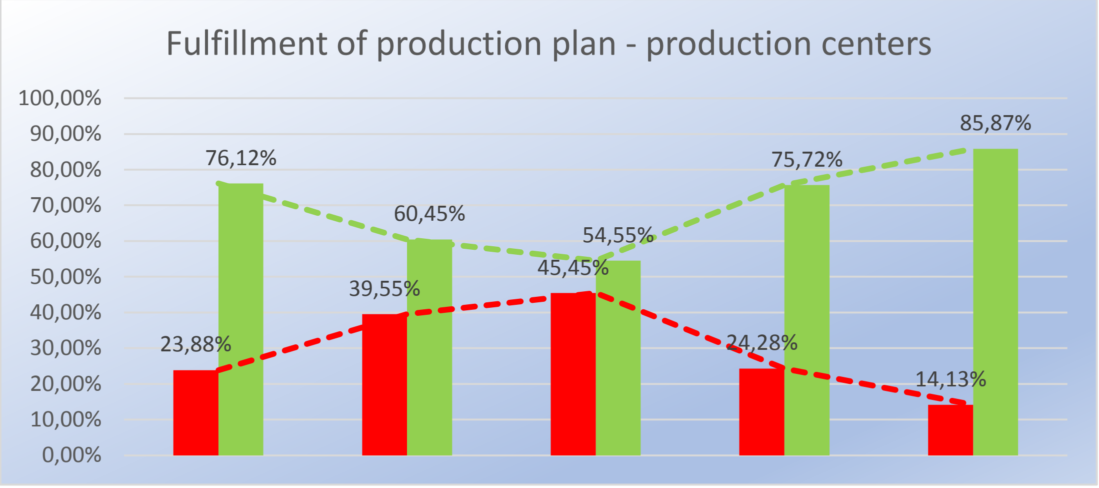

Fig.18 - Fulfillment of production plan -production centers

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In these figures, the fulfillment of the daily production plans for each week can be seen (Fig.17) and the next chart (Fig.18) shows the fulfillment of the production plan at individual production centers.

4.2.1 Design of independent simulation and Vericut verification solutions

An integral part of digital enterprises is the simulation of functional products. The simulations can model a variety of product states for optimal production. Simulation Vericut within Industry 4.0 fits into SMART FACTORY.
It allows us to:

- eliminate possible errors that occur during programming
- check the shapes and dimensions of the workpiece
- increase labour productivity, and CNC program credibility for the operator
- reduce the number of CNC program checks on the machine using NC code optimization, the production capacity of CNC machines will increase

The implementation of software will result in:

- elimination of unproductive processes on CNC machines
- software directly verifies the NC program, uses exact workpiece modeling
- software can directly optimize NC program to increase productivity of CNC machines
- system can simulate machining of the workpiece on several machines, which is an advantage in terms of capacities to determine optimal machine

Exporting of the machined model for further use is another benefit that will help increase productivity. Optimization will enable when withdrawing more material than the need to slow down the feed rate. When less material is taken, higher feed rate is used. Depending on the amount of material immediately taken, the feed rate is automatically recalculated and, if necessary, additional NC lines are inserted. NC lines rewriting runs without changing the tool trajectory of motion, which is the advantage from the capacity point of view to determine the optimum machine.

If SW Vericut is compared to Internal Verification, the difference can be seen in the following table.

VERICUT vs. Internal verification		
	Internal simulation	Vericut
Block CAM license	Yes	No
G code verification	No	Yes
Handwritten G code	No	Yes
Multiple machining sync	No	Yes
Storable accurate model	No	Yes
Slowdown with increasing complexity	Yes	No
Multi Setup Verification	No	Yes

Table 7 - Vericut vs Internal verification

(Source Internal Document AxiomTech)

Designing a solution for the company:

- Introduction of simulation and verification system after postprocessing
- Virtual 3 D model outside of the machine proves to verify CNC programs
- Decrease machine setting, eliminating downtime
- CNC operator will not have to set the program which eliminates potential collision and non-conforming product and damage of the tools
- Out-of-the-box simulation can accurately analyze the machining time

4.3.1 Self - control in the production process

Due to the relatively high non-compliance, it is appropriate to introduce incentive competition for production workers and at the same time increase the responsibility for manufactured products. One of the tools proposed is the Quality League..

By introducing the Quality League the following benefits are expected:

- reduce the number of complaints and non-conforming products
- reduce the cost of complaints and non-conforming products
- timely disclosure of a non-conforming product which enables to meet the planned date to the customer
- quality of the manufactured products according to the customer's requirements
- motivation of workers to detect non-conforming products in the production process

4.3.2 Automated reading of energy consumption

In the framework of the work, the implementation of an automated data collection system with 26 measuring instruments and with a control system is proposed enabling to monitor monthly, hourly and 1/4 hour electric power consumption, to monitor the state of reserved capacity overrun and to process the data for cost sharing to individual centers in the enterprise. Benefits of installing automated data collection and control system are:

- keeping the reserved capacity in the enterprise at 1.1MW without increasing the monthly charge for reserved capacity
- monitoring the ¼ hour of electricity consumption and taking real time measures for not to exceed the set limit of reserved capacity
- excluding the subjective factor of incorrect noting down of the billing instruments and transcription of consumed electricity
- creation and optimization of electricity consumption plans and observation of deviation
- direct addressing of potential overrun of reserved capacity due to execution of high energy-demanding production orders
- creating documents for real-time visualization of the energy performance of the company

A positive return on investment from this feature of the system at the cost **of 14,708 € can be seen in 18 months.**

4.3.3 Responsibility Assignment Matrix

A proposal to secure qualified personnel is to perform Responsibility Assignment Matrix (RAM) method on CNC machines with the aim of increasing the professionalism of the workers.

Level	
x	range = unqualified qualification
0	range 0-10% = unskilled / new worker
1	range 10-40% = partially qualified
1x	skill range 10-40% / required to increase skill
2	range 40-70% = qualified
2x	skill range 40-70% = skilled / required to increase skill
3	ange 70-100% = fully qualified

Table 8 - Qualification levels

For individual categories of employees, it is suggested to create special training plans with motivation for subsequent shift to a higher level.

4.3.4 Design of automation of maintenance processes

In our modern era of increasing productivity and implementing Industry 4.0, the automation of maintenance processes is one of the cornerstones of success. Reducing unplanned downtime of machines and machine maintenance costs is the key to the success. To increase labour productivity, it is needed to design tools that ERP does not provide. The potential for increasing maintenance performance efficiency is seen in the following areas:

- Optimized User Interface for ERP users customized for maintenance work
- Implementation of fault analysis system and TOP downtime
- System Planning of maintenance personnel
- Management of spare parts / level supplies / ordering workflow
- Evaluation of maintenance activities
- Linking maintenance and production plans in ERP
- Maintenance performance optimization - link to OEE

To address the above areas, it will be necessary to implement a software application for machine and equipment maintenance management in the company.
The sofware application will manage the preventive maintenance, manage information for more efficient maintenance work. A proposal is to apply the PROCE 55 solution from East Gate company to enable simple implementation of company-specific solutions, to supplement existing software in the company and to add agility to business operations.

The main benefits of the solution are:

- Reliable overview of all planned and performed maintenance reports
- Fast and effective response to failure
- Optimal maintenance planning including maintenance capacity planning
- optimally controlled spare parts system, ordering and storing of spare parts
- maintenance cost report
- report on the real performance of maintenance processes and individual workers

- easily accessible documentation in electronic form (also on mobile devices)
- full functionality even in the case that the ERP system is unavailable

4.3.5 Tools for increasing OEE

When implementing OEE in the first stage, monitoring units were installed, personnel in production was trained to identify idle times and their types while the machine is not in Run-Time and information was collected in the database with access to the presentation layer for visualization purposes. Integrating with ERP is essential. For the correct registry, workers were first motivated to be able to take corrective action. The second stage of implementation focused on verifying of the collected data and reporting setting on a daily, weekly and monthly basis with the KPI parameters setting to achieve the set goal. By implementing the OEE and then the proposal of the measures, an overview report of the real-time and production progress with a comparison of scheduled standard hours versus the actual is obtained, time-based detailed reports at different levels of company management, improving of the communication.

Based on the analysis, a proposal for measures and instruments to increase the levels of OEE is defined in the following areas:

- Pre-production stages - preparation of CAM-based production records, verified by simulation and use of 3D measuring program while creating programs
- Production support – automation of maintenance of processes , SMED studies, visualisation
- Production - adherence to autonomous maintenance and 5S principles, introduction of automatic 24 hours reports in the graphics with downtimes, creating the standards for repeated products

4.3.6 Implementation of SMED study

SMED studies have been performed on individual workplaces, showing clearly the weaknesses in the non-productive times that need to be addressed. The result of the study is the reduction in the preparation time by an average of 10% and setting the standards for clamping of parts, which are repeated in the production process, despite the fact that it is a custom production type. The results of the study showed the following shortcomings, which can be seen in the table (9)

Nr.	Problem
1	Do not study the documentation and the program
2	No tools are defined in the production process
3	Miss the magnetic droplet
4	Waiting for the crane
5	Organization work
6	Technology errors, programs, design
7	Programming by the operator

Table 9 - Top problems in the SMED studies

As it shows from the study, it will be necessary to propose measures to eliminate unproductive preparatory times:

- Creating a manual for masters and dispatchers, providing training
- Reviewing the current state of clamping aids and jigs
- Creating prioritization for service activities to eliminate waiting for the crane

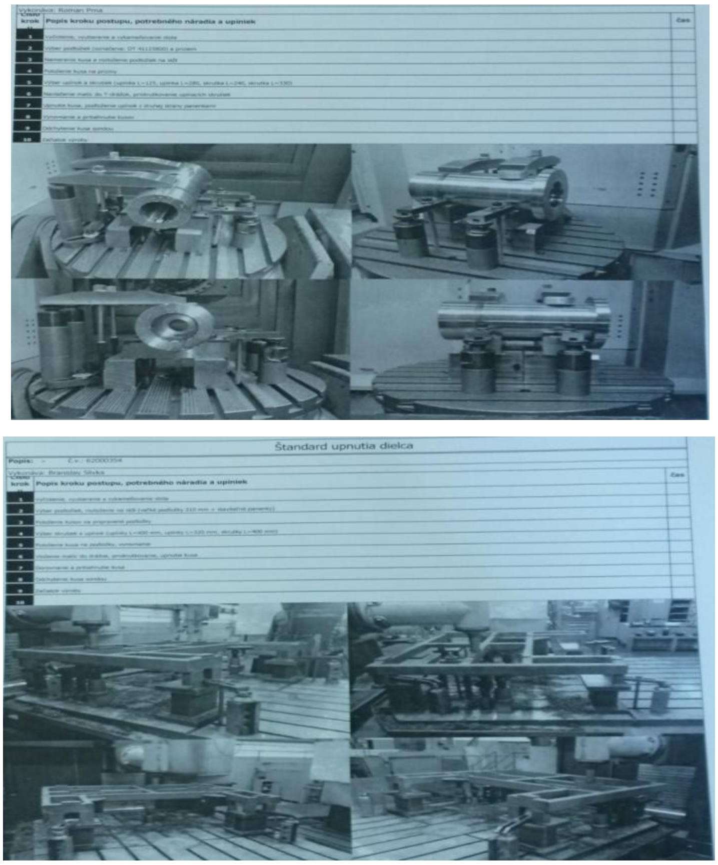

Fig.19 - Clamping standards

It can be seen in the (Fig.19) that the lengthy clamping of parts for repeated products has been solved thanks to clamping standards placed directly on CNC machines. Faster clamping is achieved thanks to the additional clamping tool in the production.

4.3.7 Visualization in production areas

The proposed solution for visualization in production facilities will enable us to:

- Identify bottlenecks - OEE measurements will show hidden machine capacities which should lead to the increase of the permeability
- Fulfillment of production deadlines - keeping daily plans at production centers shows us bottlenecks in manufacturing with the possibility to take action in time
- Changing operator behavior - when workers and their performance is visualized, this will increase the discipline with the expected result of 3-5% within one month
- Identify confusion reports - paused parts will be visualized with the number of days they have not been solved
- Monthly production plan - the monthly color production plan will monitor the current status of the work orders and highlight critical orders

The main benefit of visualization will be production clarity, productivity increase, improved employee awareness, shorter production lead times and customer order lead times.

5 SOLUTION BENEFITS AND EXPECTED RESULTS

Benefits of work solution and expected results with hypothesis confirmation are described in theoretical and practical field with recommendations for further research. The transition phase and emerging digital data are the basis for creating the conditions for starting the application of the INDUSTRY 4.0 principles and a significant source of information and knowledge usable in industrial engineering.

5.1 Teoretical Benefit

The theoretical part outlined the basic factors influencing Industry 4.0 to make the company more efficient and optimize its activities by integrating the elements of Industry 4.0. The main contribution of the work is the proposal and implementation of new solutions for processes in the described areas of research in pre-production stage, support activities and production processes. The implementation of Industry 4.0 elements, which are being analyzed in the work, will increase labor productivity, manufacturing permeability by introducing the main principles by measuring and by action steps of OEE on CNC machines, by visualization in production and by realization of automatic maintenance in the production premises of the company. The SMED program was aimed at minimizing non-production times while the manufacturing of the product, and by shortening of the given times, the workplace will be more efficient.

Another benefit is processing the reports for tracking production indicators to improve KPI indicators that will be clearly identifiable and will show areas where the current state can be improved. The planned implementation solutions and their benefits can be divided into the following areas:

- Creation of technological procedures by introducing software to standardize the time needed for manufacturing of individual products according to the latest production technologies. The regulation of the labor consumption is one of the important indicators for the calculation of the labour productivity. The creation of the 3D measuring program and the introduction of the simulation software VERICUT eliminates the non-productive processes on the CNC machines, caused by the errors that have arisen so far in the pre- production stage while programming.

- The automation of maintenance processes to analyse a fault system and TOP downtimes, linking to OEE will bring us benefits in the field of minimization of machine failures and their higher utilization.
- Implementation of OEE, data collection, setting of reporting from master level to management level, action plans will bring us benefits in increasing productivity of CNC machines The benefits of OEE can be divided into two basic areas:
    - The first benefit is the“ wow effect“ with the ability to get a real-time actual performance overview at all levels of company management. Continuous control of employees improves discipline, failure to complete a production plan allows us to take immediate corrective action.
    - The second benefit is continuous process optimization carried out by managment at various levels of company management.

5.2 Practical Benefit

The proposed analysis of the current state and of the potential for the implementation of Industry 4.0 elements as a concept of the enterprise of the future was realized in a real engineering company Matador Industries, a.s. The individual solution suggestions proposed in the company will bring benefits in the following areas and indicators:

- **Planning** – reduce labour in process manufacturing by 5% in 3 years
- **Production** – increase machine capacity by 2% annually.
- **Maintenance** – reduce production downtimes and unplanned production stoppage caused by machine failure 3% annally
- **Monitoring** – validate machining processes by monitoring and recording of data for the Overall Equipment Effectiveness (OEE) of processes on CNC machines

5.3 Recommendations for Futher Research

The further direction of research into productivity growth must be consistent with other leading disciplines. The next step in the direction of the digital enterprise is the digitization of the management of the production itself. In a company like Matador Industries, where monthly production capacity is up to 30,000 standard hours, it is essential to implement the management of the resources that should be interconnected, such as the planning of capacity resources, quality and input-output resources.

Within the further direction of research in the field of manufacturing process innovation in the custom production types, it is necessary to link the implemented solutions with key company performance indicators (KPIs). Creation of action plans and new implementation methods will bring new insights into improving corporate governance.

6 CONCLUSION

The Master Thesis deals with the issue of innovative changes in custom production. These changes are a base for using Industry 4.0 elements. Technological progress, current new trends are now the challenge for enterprises to respond to these changes in order to be competitive on the market. Based on these changes, the aim of the thesis is defined as Proposal Approach of Methods and Implementation Steps to Increase Productivity in the Production Process Using Industry 4.0. A concept and strategic approach is needed to achieve these steps in order to make the changes sustainable and capable to achieve the desired results. Realization is associated with a number of preparatory measures that need to be analyzed, planned and implemented into the current production control systems while sustaining the required quality and minimal investment costs.

The introduction of the master thesis was devoted to defining the problem, hypotheses, defining the main issues of the solution and the areas the thesis will be focused on. The next part dealt with the theoretical view of the digital enterprise of the future.

The analysis of the current state is described in chapter three, where it is pointed out that to increase productivity, it is necessary to identify the weaknesses in the pre-production stages and in the manufacturing process with the aim to optimize business processes that are interconnected. Three key parameters are important to achieve the objectives – people, technology and standards.

Another, partial goal of the work has arisen in the implementation part: *Implementation of a solution proposal for increasing labor productivity*.

In the area of pre-production stages it is the standardization in the construction phase of production, implementation of new software and harmonization of programs for control of CNC machines at individual workplaces. Sumarization of statistical reports on individual workplaces of CNC machines for evaluation of performance and quality of the production process, new system for capacity utilization and contract costs monitoring, while the duration of the project and the adoption of action plans OEE for CNC machines are dealt with in the area of producton and production support. The use of smart technology for in-house material picking for the Welding section, automated energy consumption monitoring are further cost-cutting proposals.

The result of the implementation part is the expected results in 4 key areas: Planning, Production, Maintenance and Monitoring, which have shown us that if the company sustains the proposed solutions, it will achieve the expected goals. Standardization and harmonization of programs for CNC machine control at individual workplaces. Summary of reports of individual CNC machines for evaluating the performance and quality of the production process. Within the manufacturing process, the implementation of smart technology has been proposed for in-house picking of material for the production center.

Transitional development phase for the application of Industry 4.0 principles is an important aspect of the competitiveness of enterprises in challenging market conditions. The implementation of the proposed steps and their putting into practice is the potential for increasing the productivity of the company, increasing manufacturing permeability in order to achieve set objectives. The company is characterized as an enterprise of the future, which approaches the launch of Industry 4.0 elements with a strategic vision and a clear concept.

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Abbreviations

BOM	Bill of materials
CAP	Computer Aided Design
CAPP	Computer Integrated Manufacturing
CAx	Computer Aided Technologies
CIM	Common Information Model
CNC	Computerized Numerical Control
CPS	Cyber -Physical System
DTM	DownTime Management
ERP	Enterprise resource planning
IoS	Internet of Services
IoT	Internet of Things
KPI	Key Performance Indicators
MES	Manufacturing execution systems
MRP	Material Requirements Planning
MW	Megawatt
OEE	Overall equipment effectiveness
R&D	Research and Development
ROI	Return on Investment
SG	Smart Grid
SGAM	Smart Grid Architecture Model
SMED	Single-Minute Exchange of Die
SW	Software
SWOT	Strengths Weakness Opportunities Threats
VDI	Verein Deutsche Ingenieure
Tef	Annual effective time machine
TPM	Total Productive Management

List of Figure and Table