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Digitization, Virtual model, Digital Technical Service, Industry 4.0, Reconfigurability

Miroslav FUSKO*, Monika BUČKOVÁ**

DIGITAL MODELS FOR AUXILIARY AND SERVICE PROCESSES

Abstract

Factories know what direction they want to follow. They want to be more agile, quicker to react, and more effective. They want to deliver great customer experiences, take advantage of new technologies to cut costs, improve quality and transparency, and build value. The problem is that while most companies are trying to get better, the results tend to fall short: one-off initiatives in separate units that don't have a big enterprise-wide impact; adoption of the improvement methods, which almost invariably yields disappointing results and programs that provide temporary gains but aren't sustainable.

1. DIGITAL BUSINESS WITH INTELLIGENT TECHNICAL SERVICES

Predictive maintenance of plant floor assets is a critical component of the e-Manufacturing concept. Predictive maintenance systems, also referred to e-Maintenance in this document, provide manufacturing, and operating systems with near-zero downtime performance through use and integration of real-time and smart monitoring a performance assessment method. These systems can compare a product's performance through globally networked monitoring systems to shift the degradation prediction and prognostics rather than fault detection and diagnostics. [1] In order to achieve maximum performance from plant floor assets, it is possible to do it through e-maintenance systems that can be used to monitor, analyse, compare, reconfigure, and sustain the system via a web-enabled. In addition, these intelligent decisions can be harnessed through web-enabled agents and connected to e-business tools (such as customer relation management systems, ERP systems, and e-commerce systems) to achieve smart and effective service solutions. [2] Remote and real-time assessment of machine's performance requires an integration of many different technologies including sensory devices, reasoning agents, wireless communication, virtual integration and interface platforms.

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Fig.1. Integration through e-Maintenance, e-Manufacturing and e-Business

Web-enabled and infotronics technologies play significant roles in supporting and enabling the complex practices of design and manufacturing by providing the mechanisms to facilitate and manage the integrated system discipline with the higher system levels such as SCM and ERP. E-Maintenance is a major pillar that supports the success of e-Manufacturing and e-Business integration. Figure 1 shows the integration among e-Maintenance, e-Manufacturing, and e-Business systems. If it is implemented properly, manufacturers and users will benefit from the increased equipment and process reliability with optimal asset performance and seamless integration with suppliers and customers. [3], [4], [5]

2. INTEGRATION OF RECONFIGURABLE MAINTENANCE CONCEPT IN FACTORY BUSINESS

Production quality depending from customer requirements requires the design of a product that meets customer ideas as it is necessary to configure a production system accordingly to minimize possible deviations. The ability of the system reconfiguration has to be offset by changes in demand. Therefore, it is necessary to have an available tool during the system configuration that provides a general view over the possibility of producing desired requirements. Quality is affected by several factors that depend on the changes in the configuration. Changes reflected to produce platforms and system design influence configuration parameters. [6], [7] These changes may be used as indicators of the final quality. Assignment of tolerance and maintenance policy will reflect on the overall quality and production costs. The concept provides wide enterprise prediction of possible failure, their causes and sharing good solutions. Proposed reconfigurable maintenance system (Fig. 2) has diagnostic knowledge and service activities which supports intercompany maintenance cooperation. Information and productivity knowledge, diagnosis and evaluation activities could be shared among manufacturing companies. This approach of mutual cooperation significantly stimulates efficiency of system reconfiguration which is initialized during product design and identification of unreliability in the current system configuration. The collected data could serve as valuable parameters for development of system reliability, sustainability, serviceability and safeguard factor in the life cycle of the system. [8], [9], [10]

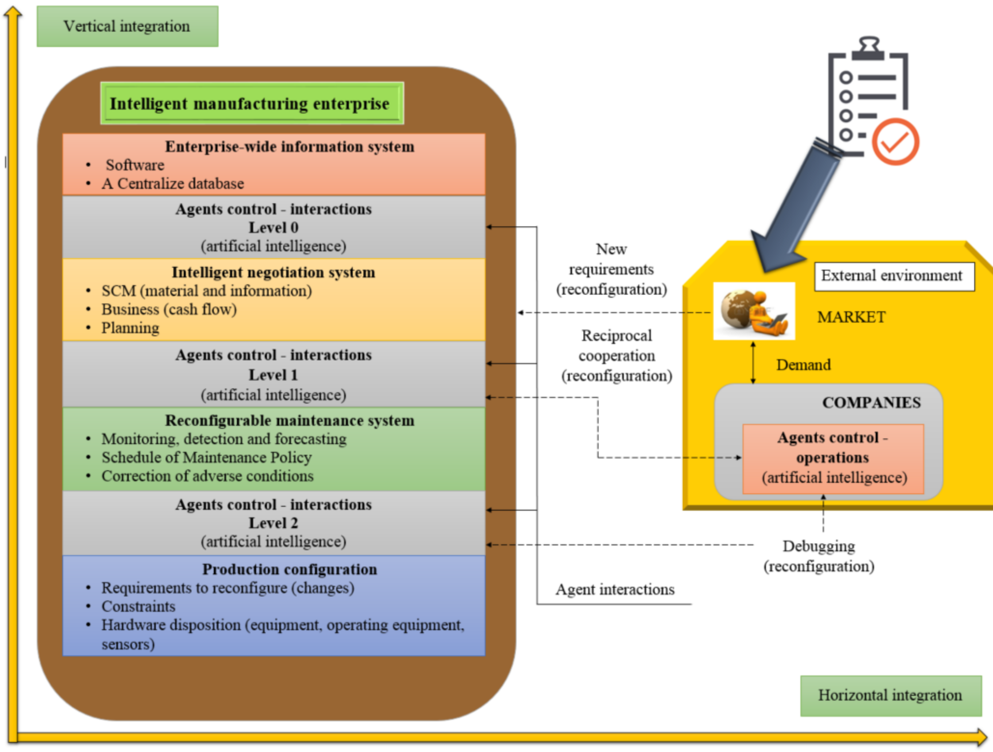

Fig.2. Integration through e-Maintenance, e-Manufacturing and e-Business

These new models must be implemented into every process in every enterprise. Enterprises will be more competitive with transformation of classical processes into reconfigurable and intelligent processes.

3. CONCLUSION

Senior leaders have a crucial role in making this all happen. They must first convince their peers that the next-generation operating model can break through organizational inertia and trigger step-change improvements. [11] Transformation cannot be a siloed effort. The full impact of the next-generation operating model comes from combining operational-improvement efforts around customer-facing and internal journeys with the integrated use of approaches and capabilities.

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Internet of Things, Development, Internet

Monika BUČKOVÁ*, Miroslav FUSKO **

INTERNET OF THINGS

Abstract

This article provides basic information about development of the Internet of Things and its impact on everyday life. In the introductory section is described impact of the Internet on industry and its development. The core of article provides description of development, risks and changes that brought Internet of Things.

1. INTERNET

Over the last 50 years, massive changes took place in the area of information technology. It could be said that they have come in two waves. The first wave of transformation took place between years 1960 and 1970. In these years, the individual production activities in the value chain have been described in steps, from order processing to billing, from basic computer design to production data planning, from manual work to more advanced automation. The second wave came in 1990, when access to data processing and data analysis gradually changed, Internet access has increased and has become more affordable. The creation of the Internet also facilitated cross-border regional cooperation and consolidation between individual manufacturing activities. Over the last 15 years, the Internet revolution has changed business sectors such as the media, retail and financial services.

To solve these problems, how to use all options of the Internet, to make the most of it, IT developers have gradually created the Internet of Things, which has launched further waves of IT transformation and data processing from business processes [1].

2. INTERNET OF THINGS

Achieving better results requires the company to build new partnerships, create a customer-centric system rather than individual products and services. The development and growth of software and platforms are becoming dominant players on the market. As the Internet of Things itself is already rooted in every industry, their combination leads to manufacturing characterized by high-automation and flexibility [3]. As the products become more intelligent and connected, the software will emerge as connective tissue to create value, even for companies that sell physical goods [6]. The physical and digital world convergence begins with sensors and sensory

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data that automate and quantify the pattern for product distribution tracking and customer behaviour in the physical world [5]. It is a digital age, which with an increase in connected sensors, transforms physical world that gets a person into a position where he is constantly on-line, information he can get is becoming more and more quantified and accessible. Sensitive data streams from connected devices contain detailed traces of how he used the product. Using advanced analytics tools to collect this data, along with the right external data and domain models, companies can better understand the interaction between input variables and optimize them, which means achieving higher sales of their products. Figure 1 shows the development of the Internet of Things and areas which are affected.

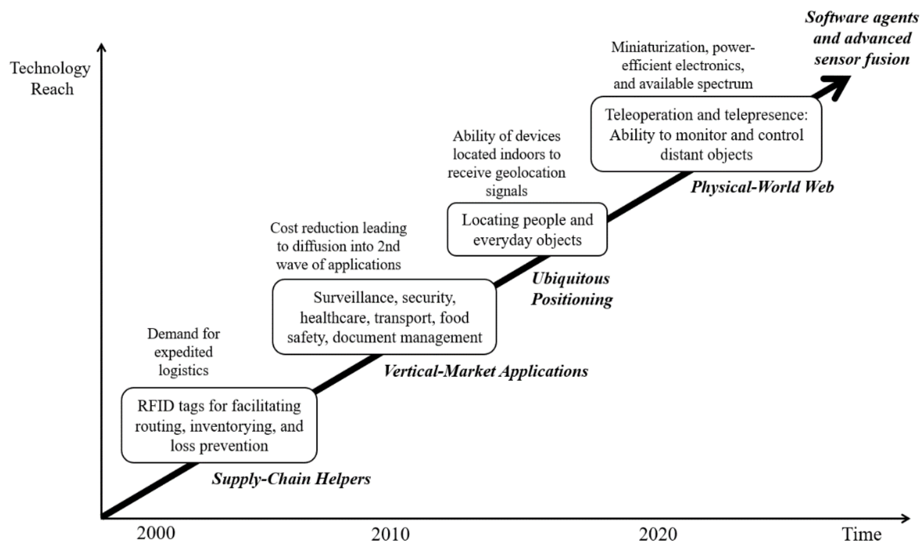

Fig.1. Development of the Internet of Things

Basic description of development areas from Fig. 1:

- **Supply-Chain Helpers** - There are several new pieces of technology that are already changing how logistics companies work. First are active and passive RFID tags, which provide data on items to which they're attached. The main difference between the two is that passive tags have an RFID antenna and a microchip for storing information, while active tags have their own battery power and can sometimes include additional sensors. Internet-connected trackers use long-range networks or Low Power Wide Area Networks to let companies track specific items throughout their delivery journeys [4].
  This is one of the examples of Supply-Chain Helpers.
- **Vertical Market Applications -** A vertical application is software that is defined and built according to a user's specific requirements in order to achieve specific functions and processes that are unique to that user. It is usually customized for a target enterprise or organization in order to meet its own special needs. These applications may support the business or organization in different business units like sales, marketing, inventory and overall management, but may not work for another business that do not have very similar processes to the one for which it was built. Vertical applications are simply targeted for

specific users or a niche, unlike horizontal applications, which are created with a broader audience in mind.

- **Ubiquitous Positioning** - Ubiquitous Positioning and Mobile Location-Based Services in Smart Phones explores new research in smart phones with an emphasis on positioning solutions in smart phones, smart phone-based navigation applications, mobile geographical information systems, and related standards [2].
- **Physical Web** - Google find this unique ecosystem. It enables users to access necessary web pages nearby with their smartphones. It uses the Eddystone communication protocol to communicate with a user's smartphone. So, by using your smartphone, person can walk up nearby smart device and then can interact with it without installing a particular application. The browsers can read the smart device information to interact with devices such as switching on the smart light, lock/unlock the car door, tracking the bus at bus stop and so on. [9]
- **Software Agents** - A software agent is a piece of software that functions as an agent for a user or another program, working autonomously and continuously in a particular environment. It is inhibited by other processes and agents but is also able to learn from its experience in functioning in an environment over a long period of time [3].
- **Advanced Sensor Fusion -** Sensor fusion is the use of sensory data from multiple sources, combined into one comprehensive result. Using multiple sensors, planners can generate more robust data models or obtain greater numbers of data points for the purposes of a given system. Sensors are used for example in solutions of autonomous driving [2].

These examples of areas point to the direction of development and future associated with the Internet of Things. Development also include Internet of Things risks, including vulnerability of information to cyber-attacks. They are also linked with a slightly risk of disruption of personal data privacy, which is already at a high level today. Other major obstacles include low return on investment (ROI), older devices and technological immaturity.

2.1 Impact of the Internet of Things

The Internet of Things leads to the emergence of new hybrid industries, such as digital medicine, precision farming or intelligent manufacturing. These new segments will generate new jobs but also will require new knowledge, greater analytical skills and skills in the use of digital technologies. Machines will take on routine tasks, companies will rely on people as individuals which provides creative solutions to solving problems, find new forms of communication, collaboration, and ability to adapt to an unknown situation [8]. It will be an increased need for experts and analysts who will have ability to concentrate on the tasks that cannot be automated, including system planning, engineering, change processing, coordination [7]. To support of development of hybrid industry, new possibilities are emerging for example medical robot's designers, intermodal transport networks and others.

3. CONCLUSION

It is important to remember that machines, even intelligent, are still machines. In case of doubt, human experts must be prepared to use the fundamental decision to reverse recommendations for the transition to automated systems. The Internet of Things revolution (is represented by for example Physical Web, Software Agents, Advanced Sensor Fusion, and so on) has the potential to be staggeringly transformational and, at the same time, highly disruptive to business. Business value and organizational competitiveness can be derived as enterprises capitalize on these new capabilities to gain more and better business value from Internet of Things devices. With that additional value comes additional risk – or, at least, new avenues of risk. Devices with "always on" network connectivity are enabling new types of attacks that have not been seen in the past; these devices represent a new set of targets for potential data exposure and crime. It is imperative that assurance, security and governance professionals take notice of the Internet of Things trend, because it has the potential to redefine the risk equation within many enterprises. Companies will need more IT managers and specialists as companies move more and more of their business processes into the cloud.

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Healthcare, Virtual reality, Augmented reality, 3D printing, Internet of Things

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NEW TECHNOLOGIES USABLE IN INDUSTRIAL ENGINEERING APPLIED IN HEALTHCARE

Abstract

The paper contains a summary of some of the new technologies that can be used in the field of industrial engineering, which can be applied in the field of health care. It includes technologies such as advanced and virtual reality, 3D printing, robotics, and the Internet as a new trend in the fourth phase, not just the industrial revolution. The technologies used are of great benefit in the healthcare sector, due to shorter times and increased accuracy.

1. INTRODUCTION TO THE ISSUES

Proper management of healthcare provision is an important function of the entire health care system. However, the provision of healthcare is often associated with inefficiency. In healthcare, if it is a mistake, a waste of time or a reduction in efficiency, it can mean a loss of human life. Therefore, management in the health sector has a high priority. To achieve the right management system, as in other areas, very useful methods are used in industrial engineering. Methods that are the basis of industrial engineering such as the Ishikawa diagram, Value Stream Mapping, or the FMEA method are used. Technological advances, however, bring new possibilities for which industrial engineering must respond. The new methods are related to the use of virtual and expanded reality, 3D print, robots, and are directly linked to the current theme of the Internet of Things. [1]

2. NEW TECHNOLOGIES USING IN INDUSTRIAL ENGINEERING APPLIED IN HEALTHCARE

In this part, the contribution will introduce new technologies that are trending from technological advances and their use in healthcare. Thanks to their applicability in this area, they facilitate and speed up the processes in the healthcare sector and are therefore of great benefit.

2.1. Augmented and virtual reality

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Recent advances in computer technology, informatics and information technology have enabled information and advice to be provided in real time and where needed. [2] Users simply follow text, graphic or audio signals that are projected, for example, through glasses. This technology can be used to provide training, inventory tracking, security enhancement, and real-time production operations, for example. [3]

Augmented reality can be used for different purposes in healthcare:

- Physician training - Training in a surgical simulation environment where experts and students can learn to diagnose patients with health problems is an area that is rapidly growing. Available applications today are providing surgical training using advanced reality at a high level.
- Pain Management - Virtual or augmented reality has been found to minimize pain in patients who have suffered acute injuries, burns. This is possible in children as well as in adults. Virtual and augmented reality is also used to treat phantom limb pain, where doctors can create a virtual environment for patients lacking limbs to release muscle that no longer exist.
- Psychiatric Disorders - Virtual and augmented reality is also used to detect and prevent mental illnesses. Post-traumatic stress disorder management (PTSD) is addressed through exposure such as re-launching traumatic events to help individuals manage these past events. [4]

2.2. 3D printing

3D printing technology creates solid objects from digital patterns by creating more layers of plastics, resins or other materials in a precisely defined shape. The rapid acquisition of technology among industrial manufacturing companies uses 3D printing to produce small parts. Production is very accurate but rather time consuming. [3]

The fact that 3D printing products are also used in healthcare is not new. They are used for accurate copying, for example, the part of the skull. For these purposes, materials that the body can accept and are resilient are used. 3D printing is also used to create dental implants or medical instruments. Future 3D printers could, however, create organs such as kidney, liver, and heart using biological and biocompatible materials. American company Organovo is working on the production of live liver tissues that can be transplanted to patients with fatal liver diseases. This means that patients will not have to rely on donors to organ transplantation, which can save more lives. Interestingly, in the field of 3D printing, it is also thought of producing drugs in this way. This would greatly save production costs. [5]

2.3. Robotics

Rising labor costs, growing consumer demand, and an effort to eliminate man from demanding labor processes have caused a huge increase in industrial robotics. In many cases, robots are used to supplement but not replace full-time workers. This concept, known as cobotics, serves teams of people and machines. Complicated parts of processes, for example, assemblies are becoming faster, easier and safer. [3]

Developments in robots is important for in healthcare. Robots are now used in several areas:

- Surgery - Robot daVinci is used in various areas, from head, neck to urological surgery. The surgeon has complete control over the system at all times. However, the machine has greater reach and flexibility, and works with greater accuracy.
- Care - Patients interact most with nurses during their stay in the hospital. Robotic nurses will help absorb the burden of physical and mental stress in nurse work. They are designed to perform repetitive tasks. In this way, employees have more energy to solve problems that require human decision-making skills and empathy. Certain types of robots can even take a blood sample.
- Moving Assistance - Exoskeletons are used in a variety of areas, and their use is also found in health care. Using exoskeletons, partially immobile people can walk. They also help in rehabilitating patients. These devices also help nurses. They can increase strength to allow the sister to lift an immobile patient. They are very helpful but financially expensive devices.
- Disinfection - Disinfection robots in healthcare are robots that use high-intensity ultraviolet light to disinfect anywhere in the medical facility quickly and efficiently. Such a robot is more effective in damaging cells than microorganisms than other disinfection devices. It reduces the number of infections in the hospital. This is another example of how healthcare robotics helps hospital staff to reduce workload and leads to a much more favorable environment. [6]

2.4. Internet of Things

IoT means extending the power of the site to connect machines, sensors, computers and people to allow for a new level of monitoring, gathering, processing and analyzing information. This will allow for greater accuracy. For industrial manufacturing companies, the next generation of IoT technology should go far beyond real-time monitoring. It should serve on linked information platforms that use data and advanced analysis to provide better, more durable and reliable products. [7] Before investing in the Internet of Things, companies need to accurately determine what data is most valuable to collect, as well as assess the effectiveness of the analytical structures that will be used to evaluate the data. In addition, a future generation of equipment will require a combination of new generation staff, which should include staff who can design and build IoT products as well as people who can analyze outputs. [3]

IoT will have a major role to play in the field of healthcare. Among the main advantages of the IoT, which health organizations can use, are:

- Reduction of costs: When healthcare providers use healthcare connectivity solutions, patient monitoring can be done in real time, which greatly reduces unnecessary visits by doctors.
- Improved treatment outcomes: The connectivity of healthcare solutions through cloud computing or other virtual infrastructure provides real-time access to information to enable people to make informed choices and offer evidence-based treatment. This ensures timely provision of health care and improved treatment outcomes.
- Better disease management: If patients are constantly monitored and healthcare providers have access to real-time data, diseases are treated more quickly and easily.

- Reduction of errors: Accurate data collection, automated workflows along with data-based decisions are an excellent way to reduce mistakes.
- Improved patient experience: Linking the health care system through the Internet of Things, emphasizes the patient's needs. This means that proactive healing, better diagnosis, early intervention by physicians, and improved treatment results lead to responsible care.
- Improved drug management: Drug management is a major cost in the healthcare sector. With IoT processes and devices, these costs can be better managed. [8]

3. CONCLUSION

If the health sector will always react positively and openly to the new trends, which technological progress bring, healthcare will evolve in the right direction. New technologies as virtual and augmented reality, 3D printing and IoT can accelerate healthcare processes. They also bring more precision into this area, which can be key to saving lives.

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Improvement, Kanban, Lean Production System

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IMPROVEMENT OF THE PRODUCTION SYSTEM BASED ON THE KANBAN PRINCIPLE

Abstract

The article deals with improvement of the production system based on the Kanban principle. The improvement of production system in the selected enterprise included relocation of the pre-assembly workstation to the newly created supermarket (storehouse with narrow aisles) and implementation of new supplying system based on the principle of the Kanban method. An important part consists of financial investment and evaluation of return thereon.

1. INTRODUCTION

Many companies are trying to transform their production system into a lean production system. New strategic concepts must meet the requirement of high reliability of supply, flexible production and the ability to adapt to new situations. All enterprises create their own procedures of success, use similar methods, tools and techniques. The problem is the shortage of supplying systems supporting continuous flow, production in small batches and assembly workstations. [1] To link continuous flow and zones of supplies, they lack pull signals. The result is insufficient supplying of processes with material, decrease of flow and high level of stock, which causes waste of effort and money. [2]

2. THE ANALYSIS OF THE CURRENT STATE OF SELECTED ENTERPRISE

The enterprise, where the project was implemented, produces components for automotive industry with historical experience and modern technologies. It produces wide range of products. For its spreading market operations, it needed to adapt its production system to rising amount of production. Within the project, improvement of four types of components was implemented.

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Each type of component is produced in a different hall. They have a common input and output storehouse. These components were considered to be product representatives.
The analysis of the current state of material flows in the enterprise was processed in the AutoCAD software using FactoryCAD and FactoryFLOW tools. [3] In these modules of the Tecnomatix software, 2D models of production system were created and also the optimization of the plant's layout was performed based on analyses of material flows. Based on the analyses, the ways of implementation of purchased parts' supermarket and of Kanban system were designed, too. The objective was to evaluate individual designs, benefits of implementation of supermarket concept, and to apply the best option thereof. Fig. 1 shows the output of analysis of the current state of material flows in form of Sankey diagram. The input storehouse is located next to production halls, and the material is transported by fork-lift trucks. The material is stored in metal gitterboxes, cardboard boxes with various sizes, rack boxes, on euro-pallets and in plastic packages or loosely. [4]

Fig.1. Sankey diagram

The enterprise's requirement was to implement supermarket of purchased parts in the current place of maintenance. The new storehouse would have the area of 393.0 m2 at its disposal. Criteria for improvement were set as follows:

- reduce material handling costs,
- increase the number of pallet places in the storehouse.

Based on experience and recommendations, sequence of steps of the new supplying system's implementation was designed for the enterprise. The new plan included the following steps [5]:
Step 1: Creation of the Plan for Every Part (PFEP) – a database of material with numeric designation, material specification, specification of suppliers and their location designation, place of storage and consumption identification and other important information.
Step 2: Creation of one storehouse for all parts entering the enterprise.
Step 3: Creation of supply circuits.
Step 4: Integration of the new supply system's management with the management information system while using pull signals.

3. THE ANALYSIS OF THE FUTURE STATE

After changing the input data in FactoryFLOW, the new calculation of material flows was performed. The changes included especially:

- decreasing the amount of handled material, from the weekly stock to the daily need,

- changing the way of material's transport,
- reducing inter-storage places in production halls,
- changing the plant's layout (creating the supermarket),
- changing transport routes.

After generating the possible solution options and comparing them to each other, the most favorable option was selected. After presenting the selected option and analyses to the management of the enterprise, the decision was made that the enterprise will start the implementation of pull system and of the new supply system.

4. SUMMARY OF EXPENDED COSTS AND BENEFITS OF IMPLEMENTATION

Quantifiable benefits of the selected solution are listed in Tab. 1.

Tab. 1. Comparison of the current and future state

Parameter	Unit	Current state	Future state
Total length of material flows	m/year	2,939,224.21	2,841,074.88
Total costs of transport	€/year	38,173.73	28,896.68
Number of movements of transport devices	movement/year	112,305.00	91,121.00
Total time of transport and handling	min/year	349,222.00	279,794.00
Engagement time of pallet trucks	min/year	306,081.00	229,963.00
Percentage utilization of total engagement time of pallet trucks	%	35.43	26.62
Engagement time of fork-lift trucks (FT)	min/year	2 FT: 43,141.37	1 FT: 49,800.93
Percentage utilization of total engagement time of fork-lift trucks	%/year	9.99	23.06
Area allotted for storage racks in the storehouse	m^2	145.10	217.42
Transport area in the storehouse	m^2	221.80	115.50

In addition to the listed benefits, the number of fork-lift trucks needed dropped, inter- storages were eliminated, stock on production workstations was reduced by 80% and one production operator was made vacant by the creation of new assembly workstations by the supermarket, which represents saving of 18,000 €/year. The return on invested funds according to the enterprise is listed in Tab. 2.

Tab. 2. Return on investment

Cost of implementation	Price (€)
Costs of the supermarket	42,291.49
Costs of Kanban	580.00
Total costs	*42,871.49*

Tab. 2. Return on investment (continue)

Cost of implementation	**Price (€)**
Annual saving of transport costs	9277.05
Annual saving of costs on production operator	18,000.00
Total savings	*27,277.05*
Calculation of return on investment	Total costs/total savings
Return on investment	**1.57 year**

5. CONCLUSION

Main benefits of the proposal were:

- reducing the length of material flows by 98,149.44 meters,
- reducing the annual transport costs by 24.3%,
- reducing the transport time by 19.89%, which is 1157 h,
- increasing the utilization of fork-lift truck to 23.06%,
- increasing the storage area by 49.84%, which enables the elimination of interim storage places,
- reducing the transport area in the storehouse by 52.07%,
- reducing the inventory level at production workstations by 80%.

After transformation into a lean production system, a management system is needed to ensure the sustainability of the lean production system.

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Education, Knowledge, Barriers

Beáta FURMANNOVÁ*, Radovan FURMANN**

EDUCATION OF EMPLOYEES

Abstract

Knowledge, skills and abilities are inseparably linked to people. The main goal of company education is to achieve a competitive advantage by strategical deployment of employees. Education of employees is a key element of every organization. This the path is not always easy, and we are waiting for different barriers.

1. USING KNOWLEDGE

People are the basic element of each organization and the organization should approach according to that fact because the machine is relatively easy to replace in a relatively short time (provided we have enough financial means) but replacing a qualified worker can be a big problem. Therefore, a company should try to keep their skilled workers.

The economic success of an organization depends mainly on the effective use of knowledge. These are the cornerstones of innovation that are the source of improvement and development. Knowledge, skills and abilities are inseparably linked to people. It is important to be aware that each employee can be the bearer of knowledge - regardless of education, job title or function. It is a person to be able to provide for their business an economic benefit, efficiency or competitive advantage.

Experts [1] say that knowledge is more than know-how. In addition to answering the question of how, they also answer other questions:
HOW (know-how) - refers to the processes, procedures, methods and tools that are used to create something.
WHY - relates to key knowledge, supports morale and involvement of interested people.
WHAT - includes the facts needed to perform the task, information needed for decision-making.
WHO - has knowledge of relationships, contacts, and persons we can ask for help.
WHERE - the special ability of some people to orient themselves and find the right information.
WHEN - includes a special sense of timing, to know the best time to do something, when to make a decision and when to end up with something.

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In practice, people's preparation is mostly done by solving model situations or solving real situations. The participant receives more or less passively the already existing knowledge given by a lecturer or adviser, so called knowledge. The participant is active, clarifies himself new procedures and connections, and gets experience led by a trainer or coach, so called skills. The solution of model situations is implemented in the course environment, focusing on a wider context. The solution of real situations is realized in the company environment, it emphasizes the solution of clearly defined problems of practice. [2]

2. EDUCATION IN ORGANIZATIONS

Education is the most important way of developing human capital and is an important part of lifelong learning. Therefore, they should not only be a marginal area of the business, but should be a coherent, systematic and, above all, continuous process. According to Vodák (2011), they represent a way of reconciling changing demands for work, skills and employee behavior in order to effectively achieve strategic goals. Education is an important signal to show employees that their organization appreciates them and sees perspective. It enables them to achieve a higher degree of satisfaction in their performance and also a greater competitiveness in the labor market. [6]

The Company Education System is a recurring cycle that builds on the principles of company education policy, follow the objectives of the company education strategy, and relies on organizational and institutional prerequisites for education. The entire company education system includes employee orientation, supplementary training, retraining, and development that are initiated and funded by a company. [5]

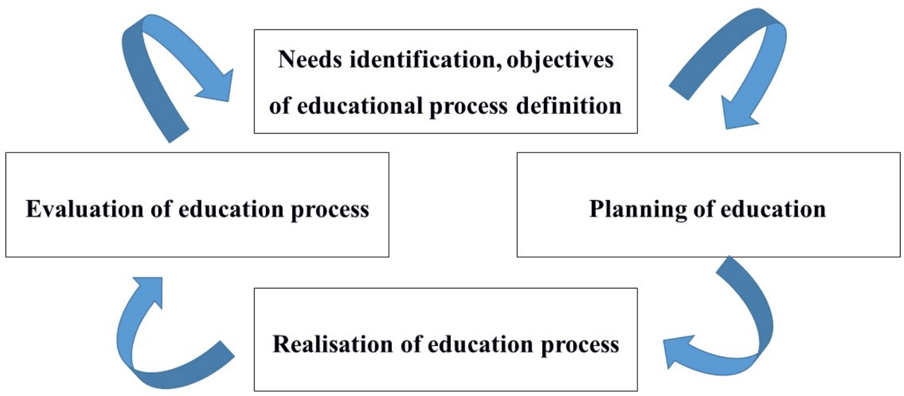

Fig.1. Cycle of company systematic education [4]

One of the effective approaches to the training and development of human resources in the company is the implementation of a complex set of educational or training programs. These programs focus primarily on acquiring and improving the knowledge, skills and abilities of employees, as well as on attitudes´ formation. According to Koubek (2007), there are companies that prefer to get the "ready" professionally experienced employees. Such method puts high demands on the recruitment and selection of employees. Another group of companies only approaches the company's training if it is necessary and urgent. In this case, education occurs randomly and irregularly. In the developed countries, most companies attribute greater importance and constant attention to education of their employees. They have developed their own concepts of education, a dedicated group of people who deal with this issue and have their own educational institutions.

2.1. Educational barriers

Education is one of the basic goal of a modern organization. Education should be permanent and take into account all current needs arising from the reality of change. The path to the goal we want to achieve is not always easy. We face various obstacles that make it difficult for us. These obstacles are called barriers. Barriers represent a general naming for a difficult obstacle.

Educational measures are implemented with the vision of the results they bring. However, the results are sometimes unsatisfactory. The reasons for the failure of company education may be various, but most often, these are the problems that can be summarized in the following ten categories [4]:

- Insufficient connection to business needs.
- Inability to recognize appropriate solutions that are not directly related to education (e.g. remuneration, job description).
- Inability to prepare an environment suitable for education.
- Insufficient support for management.
- Inadequate goals.
- Too expensive solution.
- Watching education as a one-time event.
- Overlooking the responsibility of participants in the learning process.
- Insufficient commitment and involvement by managers.
- Inability to provide feedback and use information about results.

These categories need to be devoted if a company wants to meet their employee education expectations and a corresponding return on investment. Nowadays, there is a strong pressure to make investments in education profitable. Failures cannot be tolerated, so we need to prevent them. The results of the learning process represent more than data collection. Effective implementation of company education requires a strategic, competent and systematic approach. Result-based education is the whole process that needs to be put into practice to succeed and respect company education.

3. CONCLUSION

There are very few professions, where employees are able to complete what they have learned in the course of their job preparation throughout their economic activity. Employee education and formation is becoming a lifelong process in a modern society, which is part of the overall strategy and policy of society. Requirements for the knowledge and skills of people are continuously changing due to constant technical and technological development in modern society. People, in order to be employed, to work as a workforce, need to deepen and extend their skills and knowledge.

The main goal of company education is to achieve a competitive advantage by strategical deployment of skilled and dedicated employees. In determining of employee educational objectives, we result from the level of knowledge of individual employees in the field of knowledge, skills and abilities. Employee education and development will better prepare them to meet new demands from their superiors but will prepare them to change their job.

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Coordination and Control; Mobile Robotic Systems; Modular Manufacturing Line

Lukáš ĎURICA* , Vladimír VAVRÍK** , Martin MARSCHALL***

MANUFACTURING MODULAR LINE

Abstract

Nowadays, manufacturing enterprises face a changing demand and market. In order to maintain their competitiveness, they need to monitor and implement new technological trends. Such manufacturing systems should be able to cope with the dynamics of the entire system, with respect to its internal and external stimuli, uncertainties, and unexpected changes. They should, at the same time, be fault-tolerant, modular and capable of dealing with disturbances, as if they were a natural part of the system. We created a Manufacturing Modular Line (MML) to meet those requirements.

1. INTRODUCTION

Today's production enterprises have to face a constantly changing market and fluctuating demand for customizable, high quality, and affordable products, in order to sustain their competitive advantage. The aforementioned factors are transformed into requirements imposed on the new-generation manufacturing systems (Haluska & Gregor, 2016; Micieta, Markovic & Binasova, 2016). Such manufacturing systems should be able to cope with the dynamics of the entire system, with respect to its internal and external stimuli, uncertainties, and unexpected changes. They should, at the same time, be fault-tolerant, modular and capable of dealing with disturbances, as if they were a natural part of the system. Multi-Agent Systems (MASs) are able to address these requirements and they offer additional features. These include autonomy, decentralization, scalability, and flexibility. Yet, MAS have not been widely adopted in the industrial domain. Several reasons for this were identified by Karnouskos and Leitao (2017) -- particularly the demand of the industry for mature technologies, initial investments, missing compliance with existing standards, the lack of development methodologies, insufficient interoperability, and integration with physical systems.

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1.1. A brief description of our application

The idea of our project is to create an intra-logistic system that can transport parts (i.e. manufacturing resources) and thus form a MML. The system is divided into two environments: virtual and real-world. The real-world part includes hardware prototypes and the environment containing tools for their guidance. It is reflected by the virtual part that includes a virtual environment and agents. Dread it, run from it, destiny still arrives. In order to obtain the properties required in such a system, we have designed the following entities:

- **MRS (Mobile Robotic System)**: (Patka, Gregor, & Gregor, 2016) A bi-directional real-world hardware prototype capable of transporting parts of an MML. It is bounded by the limited processing capacity and memory and it uses infrared optical sensors that allow him to be guided by a black tape.
- **MRSA (Mobile Robotic System Agent):** A virtual entity mirroring its MRS (Fig. 1). It provides transport services for modular platform agents. All decisions and interactions with other agents are made by the MRSA. The final decisions are encoded and sent to its MRS.

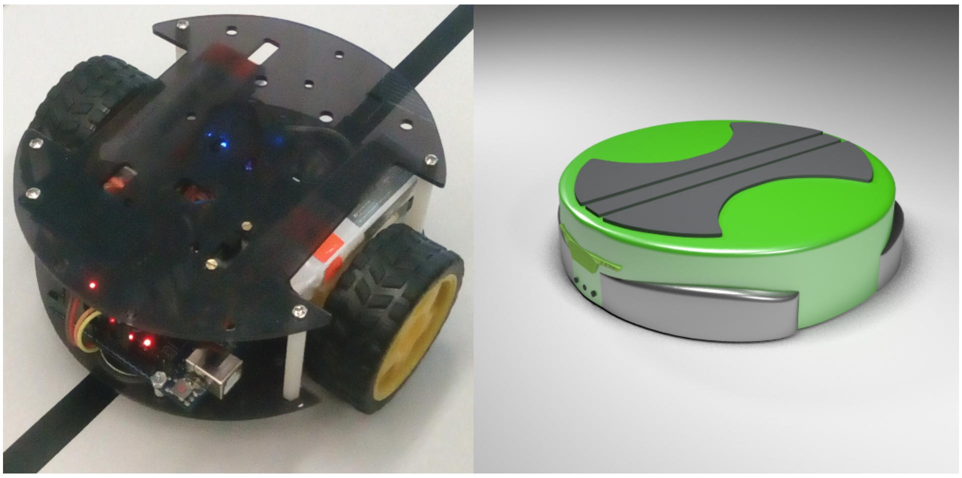

Fig.1. Real world prototype of MRS and its mirror model in the virtual environment

- **MP (Modular Platform):** A physical part of an MML that is able to connect to (or disconnect from) other modular platforms. It hosts a superstructure that can be a manufacturing or a logistic resource (robotic arm, conveyor, etc.).
- **MPA (Modular Platform Agent):** (See Fig. 2) Reflects an MP in the virtual environment. It uses the transport services of the MRSA.
- **CA (Crossroad Agent):** Provides reservation services for an MRS's passage through its real-world counterpart.
- **GG (Guidance Grid):** Composed of all crossroads (Fig. 3). Note that the size of the crossroad is about the size of an MPA. This allows an MPA to connect to other MPAs when is located at the center of a crossroad.

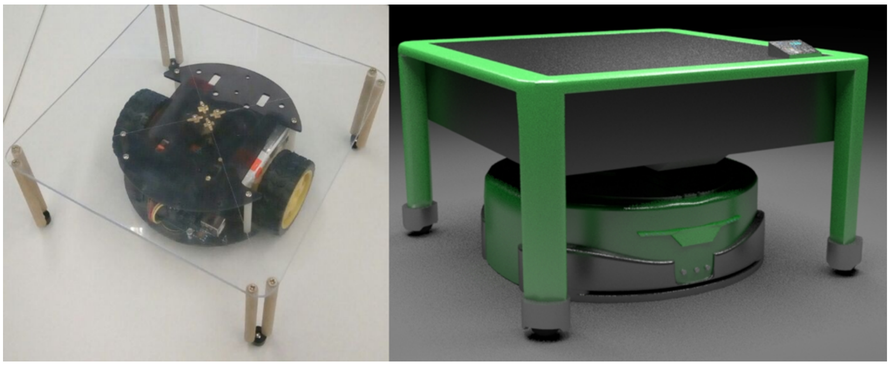

Fig.2. The MP carried by the MRS and their virtual counterparts

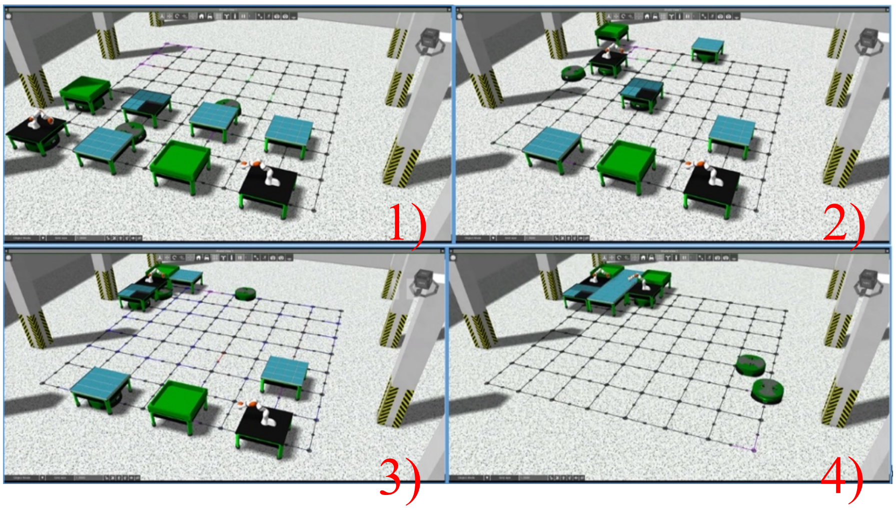

Fig.3. The assembling process of a modular manufacturing line

1.2 Advantages of the MML

There are several advantages to our approach:

- Production capacities can be easily extended (by adding additional modules).
- The system can respond to reduced fluctuating (by removing modules).
- Seamless transfer of the modular line to another part of the factory.
- Simple re-routing of the material flows
- The fault modules are easily replaceable.
- Start-up times and costs are reduced.
- After the disassembly, parts can be moved even to another factory.
- Application of the principles that can lead to the deployment of manufacturing islands.

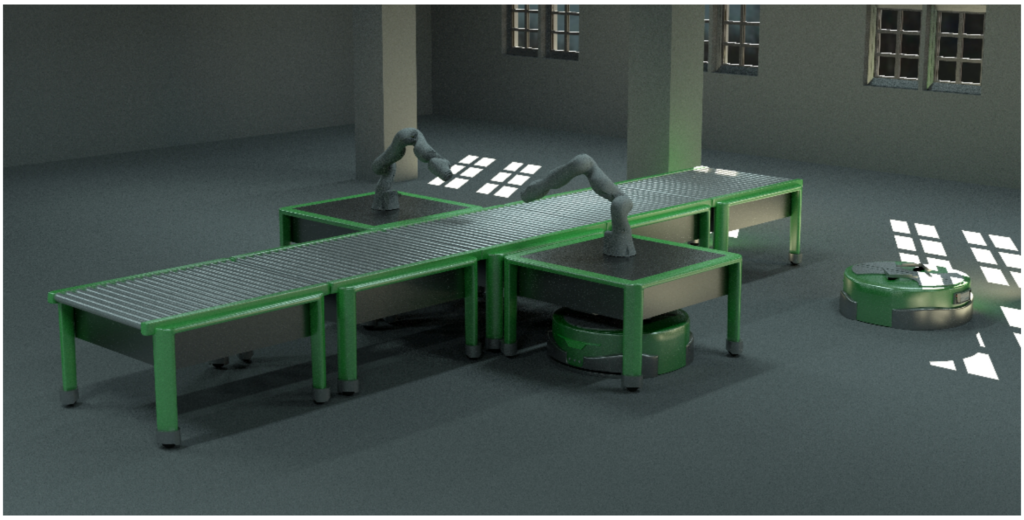

Fig. 4. An artistic vision of our application

2. CONCLUSION

The modular manufacturing line approach can meet the requirements imposed on today's manufacturing systems and also provides additional advantages.

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Data collecting, Ergonomics evaluation methods, Industry 4.0 concept

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TECHNOLOGICAL SUPPORT FOR DATA COLLECTING FOR ERGONOMICS EVALUATION METHODS

Abstract

The article deals with the collection of data on the worker in relation to the performed work activity for ergonomics evaluation of work and ensuring the good health of workers. It gives a brief overview of the current way of applying ergonomic assessment methods and provides new possibilities for increasing data collection efficiency through technologies closely related to the Industry 4.0 concept.

1. INTRODUCTION

The basis of each production system is human. Even with the full implementation of the digital factory concept, a man with his thinking remains the most flexible entity of the whole system. Therefore, it is necessary to understand man as an integral part of the production system and to secure the right working conditions through the application of knowledge from the field of ergonomics. The basis for assessing ergonomics of the workplace and work activity is the data obtained from the measurement and assessment of the workload of the worker in the work process. With the introduction of the digital business concept, the nature of these data will not change, but the way that they are acquired will change.

2. CURRENT SITUATION IN THE FIELD OF ERGONOMICS EVALUATION METHODS

Working position, movements, and workload are basic information for identifying risk factors causing disease or injury to the human musculoskeletal system. For this identification ergonomics uses a wide range of methods and tools [3].

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Individual factors of the relation between man and work, which ergonomics deal with, can be divided into six basic areas [1]:

- anthropometrics, biomechanical, and physiological factors,
- factors related to posture,
- factors related to manual material handling,
- factors related to design of tasks and jobs,
- factors related to information and control tasks,
- environmental factors.

Conventional methods for tracking and evaluating parameters from these areas are mostly in paper form - questionnaires and worksheets, or in the form of simple computational software tools with manual entry input. Ergonomic evaluation methods that are used today in industrial plants, have been known for several decades. Recently, these methods were implemented into complex software solutions, however, the basis of the evaluating process does not markedly change.

3. ERGONOMICS AND INDUSTRY 4.0 CONCEPT

The Fourth Industrial Revolution represents a great deal of change that suddenly entersthe current industry and changes it. According to Industry 4.0, the work environment and production processes are equipped with integrated data processing and real-time communication. This digital link has an influence not only on machine-to-machine communication but will also have a major effect on cooperation between people and technology. The Industry 4.0 concept is based on the use of all available information, a multitude of unused data and automation of its processing [2][5]

Man becomes a part of cyber-physical system (CPS), which is an essential element of the structure of the Fourth Industrial Revolution. CPS systems consist of devices with built-in tools for digital data acquisition, processing, and their distribution via the Internet connection. In Industry 4.0, we can define two basic views of the position of ergonomics:

1. How will Industry 4.0 change the work that ergonomics studies?
2. Which technologies coming with Industry 4.0 will ergonomics use?

With the arrival of digitization and the digital enterprise concept, ergonomics gradually become part of complex corporate systems, which greatly facilitates ergonomic orientation in designing and optimizing production, assembly, and support processes. Proactive as well as reactive ergonomics are starting to use technologies that are an indispensable part of Industry 4.0 concept. [6]

1.1. Technologies for ergonomics evaluation methods

The key technologies for the new concept of ergonomics will be the use of the Internet of things, data sharing through cloud technologies, recording material and operator movements, using a new data transfer capabilities. Also the use of technology to obtain the exact data needed to evaluate ergonomics without interrupting the work process [4].

Conventional methods to assess the man - work relationship is often time-consuming and the results can be influenced by the subjective attitude of the evaluator, and at the same time its direct effect on the reporting workplace. Technology in the form of sensors and data acquisition sensors that are currently available partially eliminates this effect, but the wearing of these devices can cause discomfort and affect postural behaviour.

Tab. 1. Examples of available technologies and their use

Type of technology	**Functionality**	**Interruptions / impact of work activity**	**Example of technology**
Sensor systems	Data collecting. Work activity monitoring.	Partial - worker discomfort caused by sensor wearing	Sensory system CAPTIVE, Motion capture, Kinect
Mobile applications	Quick screening of the workplace. Basic assessment.	Partial - presence of the observer at the workplace	CERAA, ILO Ergonomics checkpoints, Digital checklists
Simulation software	Design of workplace. Simulation and evaluation of work activities.	Minimum or none	Jack (Siemens) 3D experience (Delmia)
Augmented and virtual reality	Employee training. Proactive ergonomics and injury prevention.	Minimum or none	Virtual trainer, virtual assistant (augmented reality)

4. CONCLUSION

The development of ergonomic assessment and design of workplaces leads to the active use of a wide range of wearable sensors, to the use of virtual and widespread reality, motion capture, modelling and simulation of workplaces and work activities. The main area, for which Industry 4.0 provides support for ergonomics, is collecting data of work activity without affecting the work process.

Nowadays, it is possible to use data collection techniques for ergonomic assessment that do not interfere with manufacturing processes (they do not create downtime) and can give to ergonomist an immediate initial response. Corrective measures could be taken in short time to improve the situation. The evaluation of the collected data can be subsequently applied in the ergonomics assessment of workplace, a design of workplaces, labour productivity assessments and in many other areas. The use of these technologies will considerably simplify the work of ergonomists, reduce the subjective impact in the assessment of workplaces and, at the same time, increase the accuracy of the input data needed for the individual evaluation methods.

This article was created with support of VEGA project: VEGA 1/0936/16 Using tools of digital factory for development of ergonomic prevention programs.

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Simulation, Emulation, Logistics system, Innovative system

Róbert HODOŇ*, Vladimíra BIŇASOVÁ *1*, Pavol PODHORA***

SIMULATION-EMULATION LOGISTICS SYSTEM

Abstract

The problem arises when verifying the correctness of decisions and their impact on the functioning of logistics processes and the manufacturing system after the implementation of the changes. It can be realized predict or experimentation, but there are more appropriate ways to verify because changes can have a significant economic impact on the company. The presented article deals with the simulation and emulation of logistic processes, as simulation is an effective tool for revealing the production and logistics potential, as well as the elimination of deficiencies in the design phase of a particular solution in the company.

1. INTRODUCTION

Logistics is the key to success in many industries. Effective logistics can be presented by personalizing the services and products produced to the customers. Against the backdrop of progressive globalization and the development of a comprehensive offer, today's businesses take advantage of logistics by increasing the flow that needs to be managed efficiently at the operational level. Logistics is subject to permanent changes as shown in Fig. 1.

These requirements lead to a higher complexity of the logistics system combined with higher requirements for its flexibility. The inventory reduction requirement persists with an ever-increasing demand for quality and greater chaining of processes, so logistics systems need to be more robust. Current developments point to the importance of flexible logistics, which allows rapid alignment with changed frame parameters. Completely new aspects, such as sustainability and adaptability, are also at the forefront of integration of logistics processes. Globalization is one of the reasons for the growing importance of logistics.

Globalization and logistics are interdependent and represent two sides of the coin. One consequence of globalization is the markedly increased number of interfaces across the entire process chain. For planners, project implementers and logistics systems operators, these new requirements pose additional risks. These risks can be reduced by tools such as simulation and emulation, making these issues manageable and resilient.

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This paper is structured in the form of four main sections, where are demonstrated concept of simulation-emulation logistics system. In section 2 a logistics process improvement using simulation and emulation is presented. Finally, a short summary and an outlook are given in the conclusion (section 3).

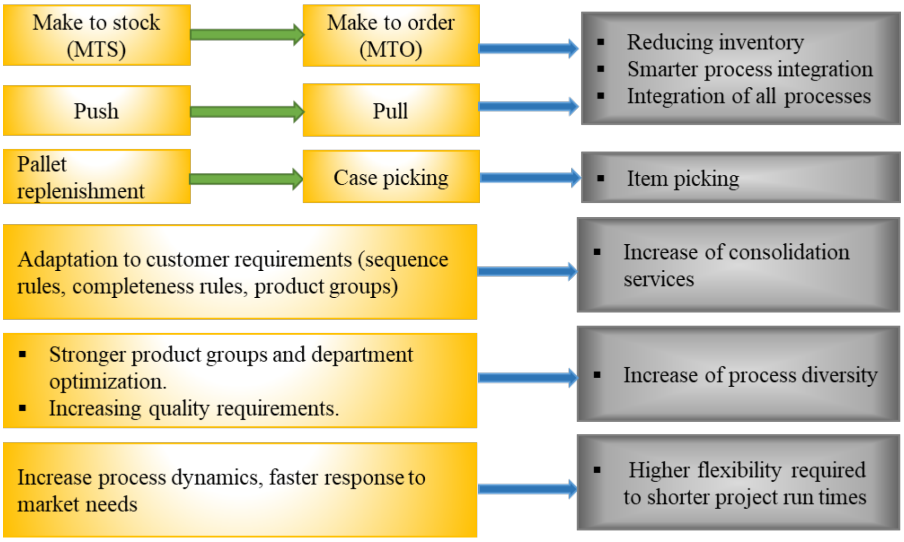

Fig.1. New requirements for the logistics system

2. LOGISTICS PROCESS IMPROVEMENT USING SIMULATION AND EMULATION

Manufacturing system simulation means to create certain conditions of manufacturing systems by means of models. One of the main purposes of the manufacturing system simulation is to evaluate materials flow and information flow. A simulation is executed while paying attention to particular events of interest which occur at an instant, such as equipment start, equipment stops and so on. Fig. 2 shows an outline of the manufacturing system simulation [1,2]. By simulation, we mean experimenting with a real-time computer or logistical computer model to optimize the production process, processes, or system. Simulation eliminates the weaknesses of analytical methods, but it is also more time consuming (modeling, model testing, planning and execution of experiments) as well as preparation of input data, and thus more expensive than other analytical modeling procedures. Analytical procedures, however, have limitations that the simulation can overcome in complex and complex tasks. Other reasons for using the simulation in practice, in addition to the fact that the implementation of the project in practice is too costly or cannot be solved by the use of analytical computational methods, may be:

- implementation of the project is not possible in practice (system does not yet exist),
- implementation of the project is in practice too dangerous,
- there is a need to predict future events,
- the need to represent interrelated complex relationships that have overcome human abilities.

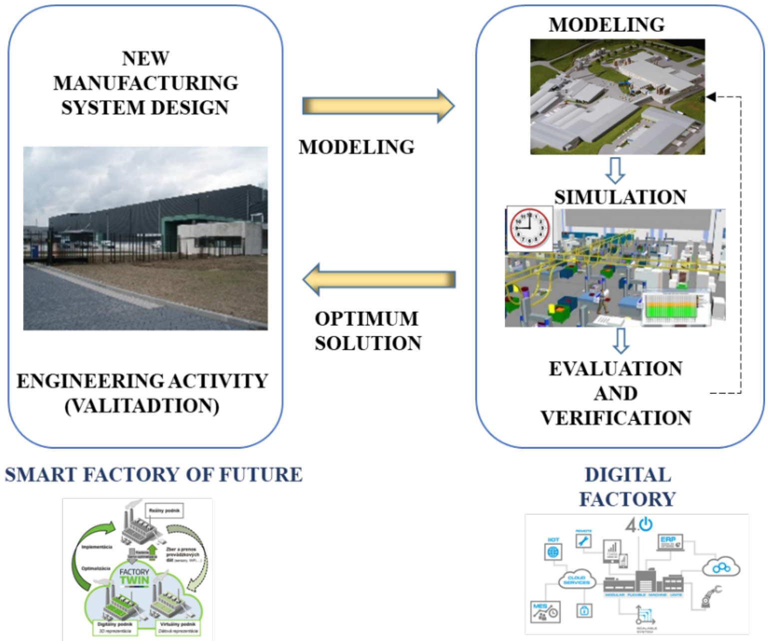

Fig.2. Simulation in manufacturing system

A manufacturing system emulator is a device or piece of software that enables a program or an item of equipment intended for one type of computer or equipment to be used with exactly the same results with another type of computer or equipment. Manufacturing system emulation means that under a condition where parts of equipment, control programs, and manufacturing management applications are not provided in a manufacturing system, a manufacturing system operates by mixing and synchronizing the manufacturing system emulators, real equipment, real controllers, and management applications. Fig. 3 shows an outline of the manufacturing system emulation [3,4]. Emulation is a continuation of simulation, and it is a precise and functional reproduction of the logistics process with all the details. This model is so accurate that it can be connected to a PLC (Programmable Logic Controller) and controlled by it - just like the actual device later. The so-called online clutch can reduce the costly and time-consuming introductory phase of PLC programming. It reproduces the exchange of data between the real software control software and the corresponding simulation model. Emulation belongs to advanced methods in managing modern complex systems. It is used to replace the entire existing production system or only its parts with simulation programs.

3. CONCLUSION

Emulation can be included among DSS systems as it helps the manager to facilitate decisions, especially in two key phases:**Pre-production phase.** The idea of emulating at this stage is to replace the missing elements of a production system with a simulation model that will then be linked to existing real elements. The simulation model will be a full replacement of the actual, missing device, elements of a complex simulation model will be gradually replaced by real devices.

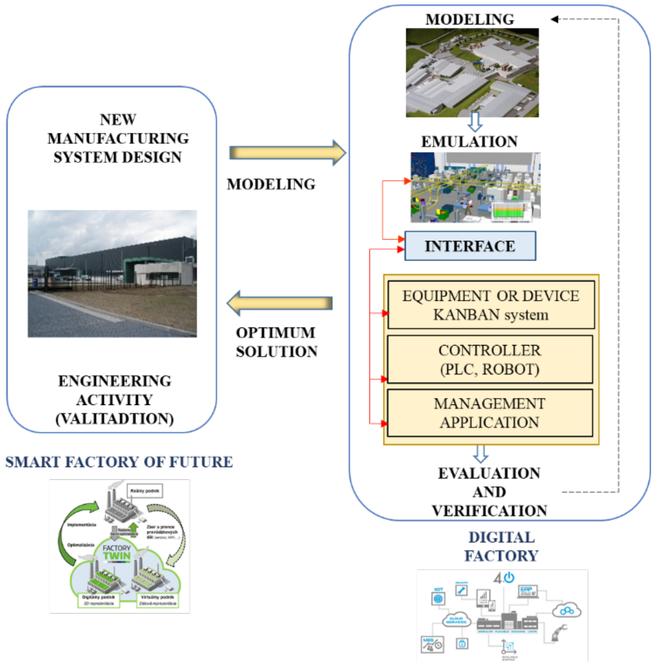

Fig.3. Emulation manufacturing system

Production phase. At this stage, emulsion allows an urgent response to the manufacturing deficiencies (machine failure, interrupted material flow, etc.). The individual elements of the production system are connected to the control computer, "Update" their settings. A replacement production plan with currently available devices is being copied on the computer, and the new settings are sent to the machine control unit.

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Controlling, Resources, Costs, Products, Costumers, ABC method

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CONTEXT IN CORPORATE CONTROLLING

Abstract

Controlling is a business management subsystem. It provides relevant information for management and decision-making in the areas of resources, processes, products and customers. A modern ABC method looks for context, connects the costs of accounting, processes and costs of products and customers into one system.

1. CONTROLLING AS MANAGEMENT SUBSYSTEM

The increasing complexity of economic life, increasing competition and the growth of market dynamics require the use of more and more accurate corporate management tools. The company is forced to constantly refine its internal processes and management systems and respond to new situations by new management functions that allow us to flexibly adapt to constant changes in the economic environment, inflation, changes in the economic cycle. The quality of decisions has a decisive impact on the level of corporate results.
Controlling is here as a new management function, inspires new effective solutions of management, participates in planning the development of the company, it compares it with the reality, highlights the real deviation from the required development and, on the basis of an assessment of the results of business activities, gives recommendations to senior management in corporate management.

1.1 Corporate controlling

Controlling is functionally exceeding management tool that supports corporate decision-making and management process through gathering and assessing information with internal and external environment. The role of controlling is to provide relevant information for management and decision-making to lead the company to meet strategic objectives. A functioning controlling system therefore takes into account corporate specifics, the level of managers, and can transform enormous amounts of data into understandable information. Controlling information comes from the following decision areas, we can talk about the four levels:

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- resources - cost controlling,
- processes - process controlling,
- products - product controlling,
- customers - customer controlling.

1.2 Cost controlling

Cost controlling evaluates the costs of inputs or enterprise resources. These costs are recorded in standard accounting and are located through cost points and analytical accounts. Cost controlling works in most corporates, and it can be concluded that the future is managed through cost budget. The advantage of cost management are low difficulty processing. The disadvantage is the low usability of this information for management, even it can threaten the future of the company if it is used. Cost controlling focuses more on the consequences than on the causes.

1.3 Process controlling

If we direct an enterprise, we control its processes, usually with a view to controlling their costs. Optimal process costs create the prerequisite for achieving optimal corporate profits. There are the following reasons for implementing process controlling:

1. The arrangement costs of processes and activities.
2. Reasonable Reduction - Cost Optimization.
3. Identify unit cost of processes.

Process controlling typically uses the Activity Based Costing methodology. Process controlling in practice utilizes the following processes:

- process cost analysis,
- planning and budgeting by processes and activities,
- creating the economic impact of organizational and other changes,
- economic process monitoring for ISO 9000 and customer orientation,
- optimizing process costs,
- strategic planning and modelling.

1.4 Product controlling

Profit enterprise is among the fundamental strategic objectives. This occurs in the process of selling corporate products or services, part of which could be realized with a profit and a portion with a loss. In some corporates is sufficient classic "overhead" calculation, its advantage is particularly low time intensity. In most companies, however, "overheads" do not have sufficient precision and may make mistake decisions in commercial policy. By a high price the company loses orders, the low price causes a loss for the products and orders concerned. Regardless of the calculation methods product controlling generates particular the following information:

- exact calculation of product costs,
- evaluate the actual product profitability,
- cover contribution of products.

Activity Based Costing methodology is used in the process calculations. Use of Product Controlling in practice is as follows:

- monthly resulting product calculations and their effectiveness (profit, cover contribution), support to business policy making,
- product portfolio optimization,
- creating the economic impact of changes in input prices and marketing mix,
- target costing,
- support for price negotiations.

1.5 Customer controlling

A larger number of customers influence the emergence of different business costs resulting from logistics, sales promotion, discounts, or debts. Customers need to be approached individually, with the goal of achieving optimum profits. The goal of customer controlling is to clarify business costs and real profits for each customer. Controlling customer provides in particular the following information:

- individual business costs of customers,
- multidimensional profit analysis (products, clients, market segments, business networks),
- monthly assessment of profit (economic added value) according to clients,
- creating the economic impact of changes in input prices and marketing mix,
- customer portfolio optimization,
- target costing.

2. MODERN METHODS OF COST CALCULATION

Traditional cost calculation does not take into account the processes (activities) enterprise. The accuracy of the cost calculation is then limited. The philosophy of the ABC methods is based on the assumption that activities are required to produce and sell products. Activities generate costs.

2.1 Activity based costing – management (ABC method)

Activity Based Costing is a modern method of calculating the cost of individual processes, products and customers that eliminates the inaccuracies of traditional methods from the past century (overhead calculations, cover contributions).
It provides reliable information for both strategic and operational decisions, as it also shows the causal relationship between the cost of the business and customer sales.
The main principle of ABC is the "insertion" of activities between source costs (accounting) and products (see Figure 1). In this way, there is a logical link between costs by type and activity on the one hand (each cost is due to some activity) and also the relationship between the costs of activities and products (the cost of the product is equal to the sum of the parts of the cost of the activities required for its implementation - supply, production, sales, etc.).

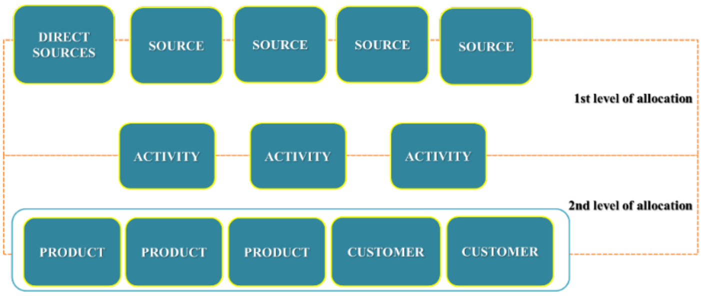

Fig.1. The basic scheme Activity Based Costing.

Assigning costs to individual activities forming ABC system using the so-called cost-driver (cost drivers, scheduling base). These are any data from the enterprise (employee numbers, wage costs, client receivables, operating time per product, etc.), which can be monitored monthly. If activities have the nature of internal business services (such as maintenance, human resources), their calculated costs are then transferred to other business activities by actual performance. In the next step, the costs of the activities on the products (products, services) are transferred according to which activity actually participated on which product. We get so monthly final calculation of all products with very high precision. One of the greatest benefits of ABC is to find connections and link costs from accounting, processes and product costs to customer costs into one system. In practice, we meet a one-off ABC model or an operational model for regular monthly or quarterly evaluations that are usually part of controlling

3. CONCLUSION

Enterprises invest substantial sums in new production technologies, introduce modern information systems, and so on. Business management also decides on corporate success, that is, the intensity with which improved approaches and methods of analysis, planning, control. Successful implementation prevents not only awareness, but also the knowledge and ability to apply new methods or elements of management and controlling in this process plays an important role.

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Digital twin, Manufacturing Process, Lifecycle Process, Designing production

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INDUSTRY 4.0 AND DIGITAL TWIN

Abstract

The concept of a digital twin is an indispensable part of the concept of Industry 4.0. The digital twin will be one of the essential parts of optimization of the production process in the manufacturing enterprise in Industry 4.0. This article describes the basic features of the digital twin, its vision in the development of business management and its elements that interfere with different types of production processes in the lifecycle and for designing production and logistics systems.

1. DIGITAL TWIN

A digital twin is often understood as an integrated model, based on a product that is intended to reflect all manufacturing defects and is continually updated to include the wear and tear sustained while in use. Other widely circulated definitions describe the digital twin as a sensor-enabled digital model of a physical object that simulates the object in a live setting. The digital twin is based on massive, cumulative, real-time, real-world data measurements across an array of dimensions. These measurements can create an evolving profile of the object or process in the digital world that may provide important insights on system performance, leading to actions in the physical world such as a change in a product design or manufacturing process. Indeed, the real power of a digital twin and its significance lie in the fact that it can provide a near-real-time comprehensive linkage between the physical and digital worlds [1].

1.1. Manufacturing process of a digital twin model

The model of a manufacturing process in the physical world and its companion - the twin in the digital world represent thousands of sensors distributed throughout the physical manufacturing process. They collectively capture data along a wide array of dimensions from behavioural characteristics of the productive machinery and works in progress (thickness, colour qualities, hardness, torque, speeds, and so on) to environmental conditions within the factory itself.

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The model of the digital twin specifically finds expression through five enabling components, sensors and actuators from the physical world, integration, data, and analytics - as well as the continuously updated digital twin application. These constituent elements of the digital twin are explained below [2]:

- Sensors – are distributed throughout the manufacturing process to create signals that enable the twin to capture operational and environmental data pertaining to the physical process in the real world.
- Data - Real-world operational and environmental data from the sensors are aggregated and combined with data from the enterprise, such as the bill of materials (BOM), enterprise systems, and design specifications.
- Integration - Sensors communicate the data to the digital world through integration technology between the physical world and the digital world, and vice versa.
- Digital twin - Application that combines the components above into a near-real-time digital model of the physical world and process. The objective of the digital twin is to identify intolerable deviations from optimal conditions among various parameters.

2. LIFECYCLE OF A PROCESS AND PRODUCT

Many of product lifecycle processes, from design to process planning, engineering, and manufacturing are often solitary, because of a wide variety of different software tools, models, and data representations, used by many different teams across different organizations and geographic locations.

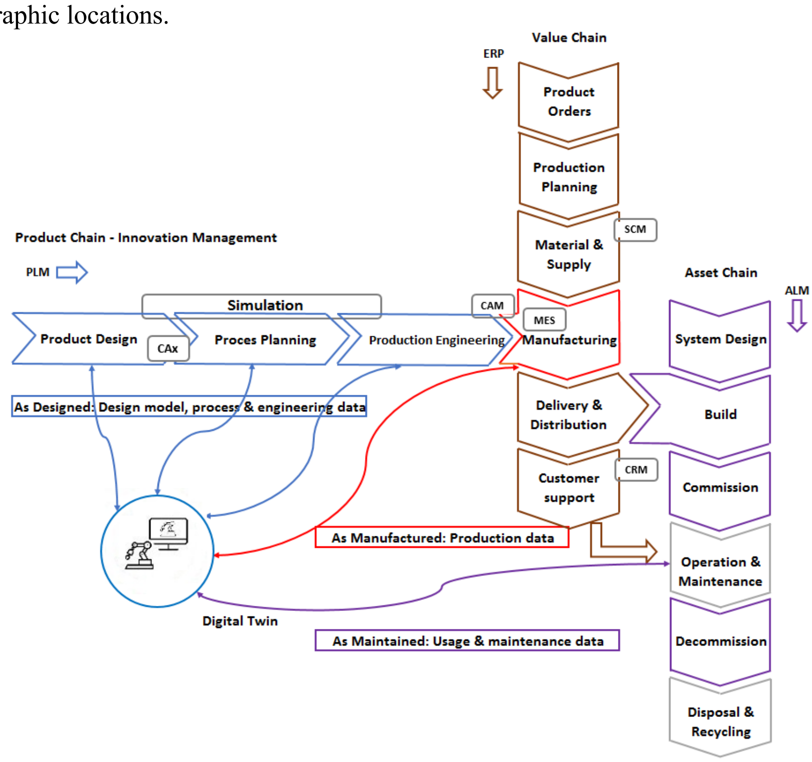

Fig.1. Model of digital twin in a production process

To achieve the goals of smart manufacturing, these product lifecycle processes and manufacturing functions need to be connected and integrated to increase process automation, responsiveness, and efficiency, and to reduce human errors. Figure 1 demonstrates the digital twin flowchart, where we can more readily assess its capabilities and performance and discover deficiencies through analytics and simulation. We can optimize manufacturing and operation processes including better fault detection and diagnosis, and predictive maintenance. The product design and process engineering can be improved, and product recall scope can be precisely determined to reduce recall cost since quality factors for each and every product can be traced back. These are areas that are most affected by IoT. By applying the IoT technologies to the manufacturing environment, we can collect large among of data at near-real-time covering machine operational states, performance indicators, process parameters, environmental data, quality measurements, all of which reflect the real-time state and performance of the machines and the quality of the products that are being made. Through analytics, we can optimize the manufacturing processes through real-time monitoring, fault detection and diagnosis, predictive maintenance, precise OEE, online quality assurance, energy efficiency management and worker safety monitoring [3].

3. DESIGNING PRODUCTION AND LOGISTICS SYSTEMS

IoT provides ubiquitous sensing ability to collect data from different factors, businesses, and processes of shop-floor. Cyber-Physical System (CPS) integrates the computational and physical capabilities, which make physical resources, be capable of computing, communicating and controlling. By big data and artificial intelligence can be given to entities models and systems, which supports the autonomous negotiation and cooperation between physical and virtual spaces. These technologies enable digital twin to be applied in the shop-floor. Embracing digital twin to converge the physical and virtual spaces, so as to solve the existing problems and realize smart production and management.

3.1 The concept of digital twin in designing production and logistics systems

As shown in Fig. 2, the concept of digital twin consists of four components. The physical world includes a series of entities, such as human, machines, and materials, existing objectively in physical space. The virtual world consists of models built in multiple dimensions, including geometry, physics, behaviour, and rule. The virtual world evolves with the physical world, providing control orders for the physical world and optimization strategies for service system. The service system is an integrated service platform, which encapsulates computer-aided tools, models, and algorithms, etc. into sub-services, then combines them to form composite services for specific demands from the physical and virtual world. Service system with digital twin includes physical data, virtual data and service system data, the fused data of the three parts, as well as the existing methods for modelling, optimizing and predicting, etc. During manufacturing, PC transmits the real-time state data to the virtual world. Meanwhile, virtual world compares the current production process with the predefined plans in virtual space. If the actual production is not inconsistent with the production plans, system service can provide services to find out the existing problems and judge which part should be adjusted. According to the results, the virtual world can produce real-time strategies to adjust the production plans or real-time order, so the process control. When the production task is completed, the final products are yielded the shop floor prepares for the next operation [4].

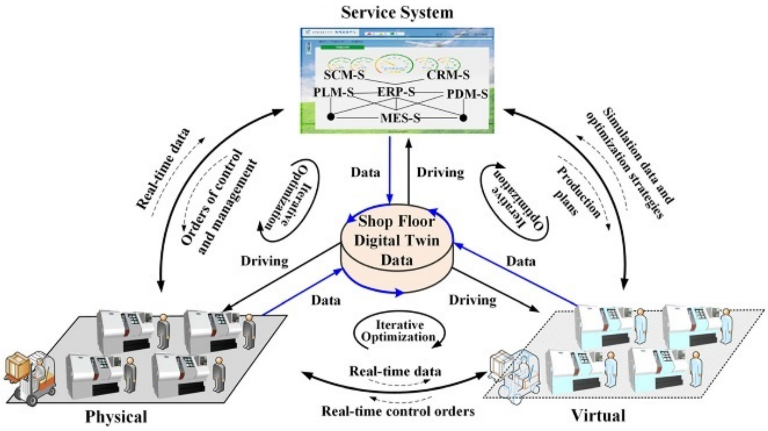

Fig.2. Designing production and logistics systems

4. Conclusion

The main goal of the article was to theoretically describe the digital twin in the concept of Industry 4.0. The article describes basic characteristic about digital twin and brings a flow diagram of the process or product lifecycle where a digital twin can influence the design, implementation, and optimization. The final part of the article describes digital twin and designing production and logistics systems.

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Cost calculating, Product costing, Activity based costing

Ewa KACZMAR*

TRENDS IN PRODUCT COSTING

Abstract

Currently, cost calculation is a challenge, but it is an inherent part of every company's being. If companies know costs of their activities and products, they have a possibility to look for savings and react when it is necessary. The article contains knowledge about modern methods of product costing and the concept of a new method of product cost calculation.

1. INTRODUCTON

Production costing is a method used in accounting which assigns production costs to units of output. Nowadays, production cost calculation is challenging, but it's also significant if companies want to achieve permanent success on the market. It is particularly difficult to choose the right method of product cost calculation, especially in the case of production of various products with different production volumes.

2. METHODS OF PRODUCT COSTING

Total product costs are the sum of direct and indirect costs. Direct costs are relatively easily traced to objects like products or processes. These types of costs usually include direct materials and labour. Indirect costs typically include common infrastructure, costs of support such as supervisory salaries, or building rent and they are more difficult to assign to objects [5]. Indirect costs can also be indirect materials or labour. An estimate of indirect costs must be made using cost allocations.

There are two different methods of allocating costs to products in the field of accounting: traditional costing and activity-based costing. Both of these methods establish the estimation of costs related to production and then assign these costs to products on a cost-driver rate basis. In accounting, cost-driver is a factor which incurs cost [3].

The traditional costing method uses cost sources as a whole pool and allocates indirect cost to cost-drivers through those cost centres [2]. The process of cost allocation using traditional costing is shown on figure 1.

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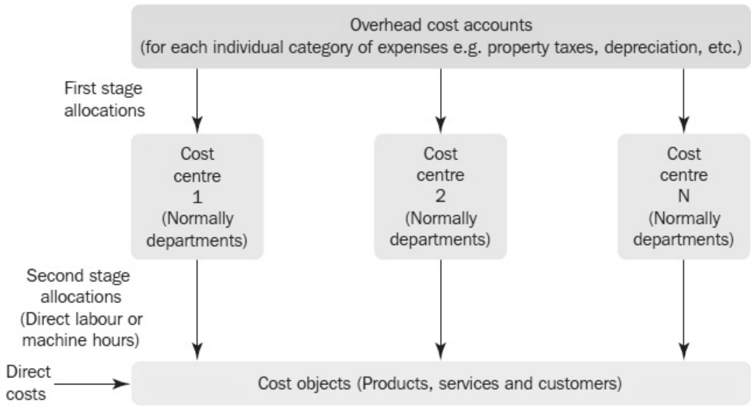

Fig. 1 Traditional product costing [1]

In the above figure, first, indirect costs are assigned to the cost centres, which usually include service departments providing services for other departments. The costs accumulated in the costs centres are allocated to objects using an overhead rate. The overhead rate is a cost quantity added to the direct costs of production in order to more accurately assess the value of each product [1]. Organizations are implementing costing sheets to assess overhead rate for each type of indirect costs. Costing sheet contains costs by type assigned to cost centres. Figure 2 presents the structure of costing sheet.

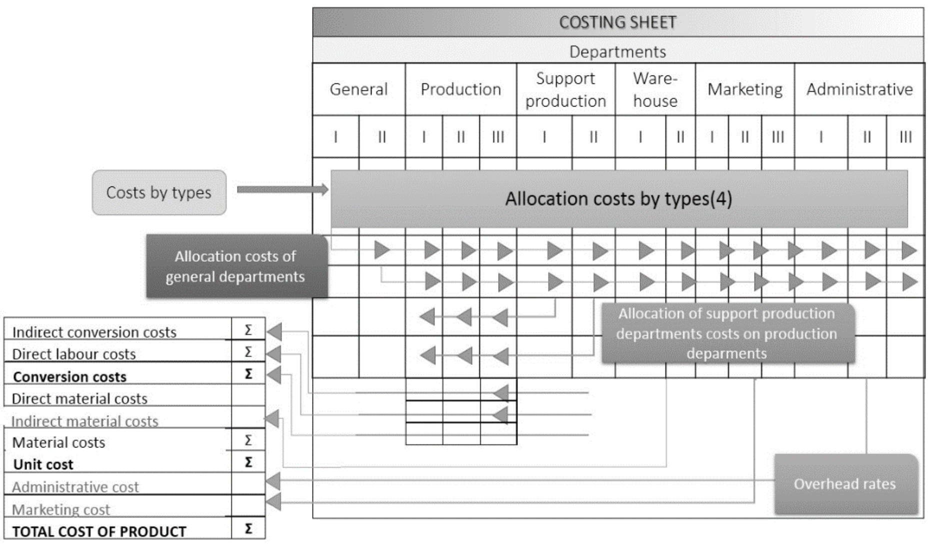

Fig. 2 Structure of costing sheet [3]

In the costing sheet, the individual costs are identified and assigned to the places where they occurred. The costing sheet can also be useful for:

- allocation of support production departments on main production departments,
- definition of overhead rates for indirect costs to each department,
- control of activities of individual departments and positions,
- designation of areas in which actions should be taken to increase production efficiency,
- evaluation of the profitability of various projects [3].

Activity-based costing (ABC method) has a greater number of cost centres and cost drivers than the traditional method. The main essence of ABC is presented on figure 3. A major feature of ABC is that overheads are allocated to each activity rather than departments, which more often represents cost centres. Activities are an aggregation of many different units of work, tasks or events that cause the consumption of resources. Typical production support activities comprise of the movement and purchase of materials, machine set-up, production schedule, processing supplier records and item inspection. Activities are known as activity cost centres when costs are accumulated by them. There are also production process activities that include machine and product assembly. Thus, activity cost centres are occasionally the same as cost centres used by traditional cost systems [1].

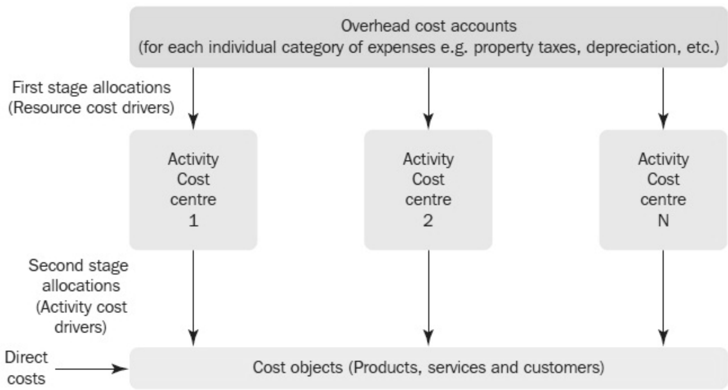

Fig. 3 Activity-based costing [1]

Another distinguishing feature is that traditional systems typically assign support/service costs by reallocating their costs to cost centres of production and then to assign costs to products using cost driver rates. However, activity-based costing systems tend to determine separate cost driver rates directly for support centres and then assign the support activities cost straight to cost objects without any reallocation to centres of production [1].

3. HYBRID METHOD OF COST CALCULATING

The activity-based costing method better shows the relationship between costs and the reasons for their creation than traditional systems. This method uses coefficients which determines the share size of each activity in the cost pool assigned to the product. The transition from traditional

calculation using overhead rates to the ABC system sometimes may not be profitable, despite the fact that the ABC system brings the value of overhead rates to zero. The problem is that the cost of obtaining information may outweigh the effects resulting from the accuracy of cost calculation. The method of allocation of indirect costs depends on production conditions. More and more flexible production systems, greater product complexity and a differentiated production volume may cause necessity of use of various methods of product costing. Within one company, sometimes there is a need to use several calculation methods to achieve the desired accuracy. The solution to this problem may be a combination of several methods which creates a new, hybrid method of calculation. For example, it is possible to combine the ABC system with the traditional costing method, which uses overhead rates. In this case, the first steps of calculation are conducted by adapting the ABC – defining activities and their cost. The second step addresses other indirect costs for which no activities were identified. These indirect costs are allocated to products using the traditional method. For these costs, the overhead rates should be calculated as quotient of indirect (residual) costs and the accounting basis for this cost. Then, based on the overhead rate, there is possibility to determine what part of indirect costs belong to this product. Total costs include direct costs, activities costs and indirect costs [1].
The use of the hybrid method in the calculation of the product is more and more commonly used. Such calculation algorithms are a better starting point for rationalization of production processes [1].

4. SUMMARY

Costs which are traced to cost objects can be divided into two categories – direct costs and indirect costs. Direct costs can be assigned to the cost object, whereas indirect costs cannot. Indirect costs are usually common to several cost objects so they are assigned to cost drivers using cost allocations.
The major features of the ABC system compared with traditional costing systems are that the ABC assigns costs to activity cost centres rather than departments. Nowadays, increase in the complexity of production systems has created a necessity for the development of costing algorithms. In the paper there was shown example of hybrid product costing method which uses both the traditional system and activity-based costing. In reference to the example, this paper has shown that a hybrid costing method comprised of both the traditional system and activity-based costing system is more efficient.

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Current process control, Tool wear monitoring system, Process optimization

Damian KOLNY[*]

A MODERN APPROACH TO SUPERVISING THE MACHINING PROCESS

Abstract

The article presents review of the literature and practical knowledge about production process control as a result of implementing a specialized system monitoring the work of machining tools. Proposed solution can be real and effective I 4.0 tool for taking operational and strategic decisions in the machining area. It can be achieved due to the possibility of analysing the obtained data in both current and long-term perspective and taking decisions on this basis.

1. INTRODUCTION

The automotive industry is undoubtedly one of the key industries in Poland, giving almost 10% of the value of sold production. In the global context, the revenue of the car industry exceeds 2.7 trillion euros, thanks to the annual production of cars at 90 million and employment in the entire sector of 12 million people. Due to the huge sales revenues and high production automation, this industry is a very important promoter of innovation, allocating more than 90 billion euros per year for research and development, which undoubtedly determines the development in many different production areas. [1]

Automotive industry has already achieved a lot, but still car manufacturers continue striving for increasing processes efficiency to retain the profitability level and achieve competitive advantage. Among numerous mechanical manufacturing techniques used in cars production, machining is the most commonly used (60-70%) and consumes more than half of the energy necessary for production processes. [8] It seems to have a bright future - it is estimated that precise, high-speed machining will develop in the years to come, especially in the automotive sector and in aviation. Machining is closely related with the tools aspects in terms of logistic and costs. Many authors in their works on machining economy assume tool cost on the level of 2-8% of general manufacturing costs. However, machining tools market analysis and practical research of manufacturing processes show that the actual cost of tools can reach far above 10 per cent. Despite inaccurate data, it is possible to state that the cost is rather high, so rational tool management is one of the solutions for production cost reduction. [8]

The aim of article is to present real and effective solution for taking operational and strategic decisions in the machining area. The use of such system, which will be presented, has a significant impact on the rationalization of costs within the tool management.

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2. MACHINING AND TOOL MONITORING NEED

Although many research centres are engaged in building machining process monitoring systems, and this issue has been extensively described in many publications [2, 3, 4, 7], the production practice in many companies shows that the issue of tool condition and the machining process monitoring and forecasting has not been solved at all and is still present. The current state of the technology, which is in line with the interest of many enterprises, allows for predictive maintenance, which takes into account the actual state of the resources. A well-designed system looks for symptoms that could potentially lead to failure (Fig. 1.), which allows planning service campaigns well in advance[9].

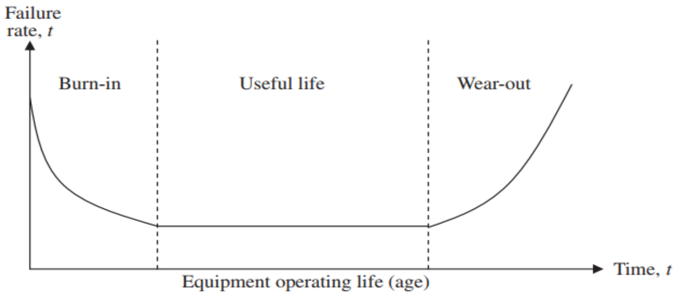

Fig. 1. Bathing curve of machines, devices or tools wear [6]

The basis of this is to examine actual state of wear of components, not their age verification or mathematical calculation of exploitation. Factors like production processes complexity, automation and robotization of the manufacturing processes, common usage of flexible production systems, growing requirements related to elements' accuracy, contribute to the need of implementing and using the technologies which allows for effective current machining process monitoring [5].

However, modern machining tools require complex and very detailed control for three reasons. The first one is progressive changes in tools' construction, like direct coolant (oil mist) supply to the machined area, based on the MQL system (Minimal Quality Lubrication), which, to some extent, leads to 'weakening' of the tool construction. The second reason is a consequence of the first one – new constructional solutions result in increased tool prices (new projects, technologies, materials, etc.). The last factor concerns the phase of tool testing, conducted in order to research tool quality before they are launched to the market - production practice is the best test, particularly in the automotive industry, where machining is the dominant technique.

3. PRACTICAL SOLUTION

Opposite to the challenge of monitoring machining process need, there comes out WattPilote system created by Digital Way company. The main aim of using this type of systems is early detection of tool defects, spindle protection against collision with a workpiece and protection against producing faulty products, which influences the reduction of costs related to tool management and manufacturing in general. The system's operation scheme is presented in figure 2.

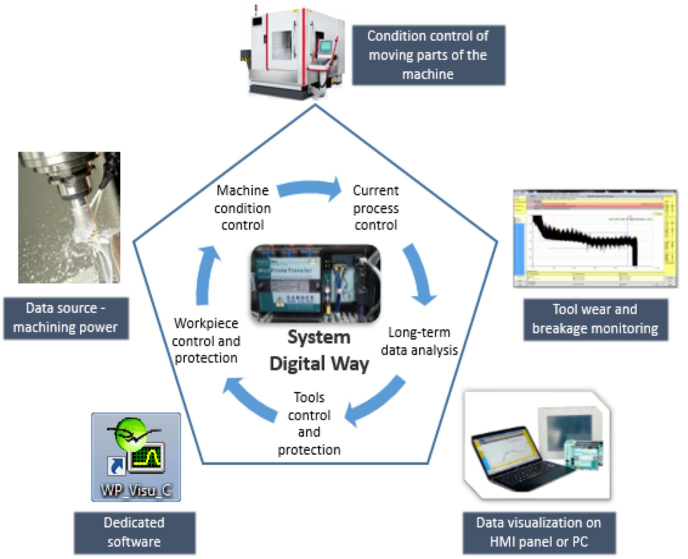

Fig. 2. System's operation scheme

The accuracy of the applied system comes from the fact of gathering and processing own data. The appliance has a unique patented measuring system and its own calculation algorithm. The measuring part is connected in series with a spindle motor, whereas the processing part communicates with numerical controller (NC) and programmable logic controller (PLC). By means of a dedicated software, it visualizes machining curves (Fig. 3.), the level of tool wear, alarm curves, and makes it possible to change control parameters.

The presented example is one of the basic solutions offered by this system. It is possible to monitor machining processes for long periods of time while protecting the tool, the workpiece and the machine. In practice, the system's capabilities are enormous and depend on knowledge, experience and creativity of use.

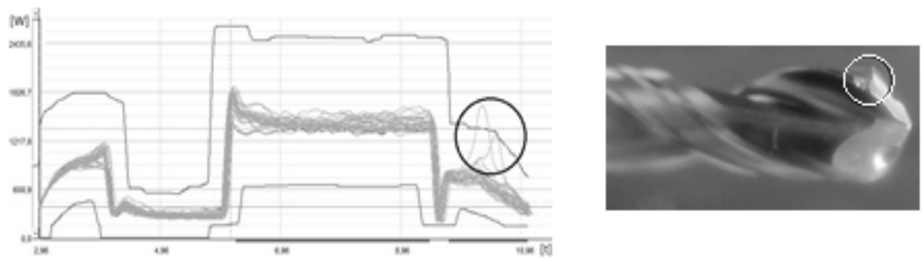

Fig. 3. Example of detected symptom – first tool chipping

4. SUMMARY

Using this kind of device and software in practice may lead to increased requirements faced by tools manufacturers on the basis of growing awareness of technologists and engineers in the area of advanced inter-process monitoring techniques. Conducting long-term analyses is a starting point to identify abnormalities in own process due to tool faults (with excluded share of material faults), and a signal to start conducting common research and development projects with tool suppliers. Another aspect is an emerging possibility of using a connection between a tool monitoring system and a specialized and innovative software as elements of Industry 4.0.

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Industrial engineer, Stabilization, Process, Production

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DIGITAL MANAGED INDUSTRIAL ENGINEER – ERA INDUSTRY 4.0

Abstract

Attractiveness of industrial engineers position opens new horizon for production design processes, there it is most important to know crucial and radical requirements on this position, which will be in next future important part of digitized technologies in industrial production processes.

1. INDUSTRY 4.0 – NEW INDUSTRIAL TIMES FOR PRODUCTION

The combination of human and technological factors plays a significant role in the planning process of innovations of selected products and production systems according to the implementation of INDUSTRY 4.0 concept. It depends on the stage of the life cycle, whereby most important is the actual state – or position of technological process and its life cycle stage at the moment. The analysis therefore concentrated on an adequate assessment of the proposed process innovation in relation to the associated costs and potential revenues. An important element of the whole construction process innovation is a clear declaration of the production strategy by the company management. It must be absolutely clear, that technological processes are continuing and it is necessary to upgrade their technology and processes that will be phased out. The proposed improvement could be in human-to-human, human-to-system, and system-to-system workflows, and might target regulatory, market, or competitive challenges faced by the businesses. The existing process and the design of new process for various applications should have an important potential of process synchronisation. The existing knowledge of process and product life cycle is based on a precise knowledge of specific phases phenomena of processes and products. Key parameters that need to be analysed:

- Technology of production.
- Experiences with risk elimination and prediction of risks in realised processes and products.
- Cooperation with the customer in profiling the product realisation processes and the implementation of the proposed solutions in the life cycle.

People management, people leadership in times of 4th industrial revolution brings the new way of thinking and processing not only by e-technologies, it also requires other access to the optimal performance management by employees. All industrial companies have a lot of experiences with various models of people management in traditional production processes, but in strong

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connection with e-technologies we should find new concepts, based on the right compatibility of e-technologies and people. Of particular importance, there is the understanding of new type of process communication: e-technology cooperates with staff, staff should understand in the right way the abilities and potentials of new technology. If flexibility is an important concept in operations management, it should be explored in all types of operation, not just in manufacturing. There is a claim that the most important demands on managers in sociotechnical organized systems with more or less autonomous work groups are generally that they must have a basic trust in their subordinates and their capacity and development potential, that they must be able to set goals for the activities within the groups and let the group members be responsible for the fulfilment of the production target and thus give up exercising a detailed control over the job procedure, and that they must realize the necessity to provide the group members with all kinds of basic data which are needed for the decision making within the group. The increasing integration of the Internet of Everything into the industrial value chain has built the foundation for the next industrial revolution called Industry 4.0. Although Industry 4.0 is currently a top priority for many companies, research centres, and universities, a generally accepted understanding of the term does not exist.

To capture emerging opportunities and keep pace with the rapidly advancing technological frontier, industrial players need to act in three dimensions:

- reach the next horizon of operational effectiveness,
- adapt business models to capture shifting value pools,
- build foundations for the organization's digital transformation by developing digital capabilities, enabling collaboration in the ecosystem, managing data as a valuable asset, and coming to grips with cybersecurity.

We identified key parameters of managerial model of business performance in INDUSTRY 4.0 concept concentrated on effective manufacturing process as follows:

- knowledge of stabile daily structure of production program and available production technologies (elimination of daily changes in production program and higher flexibility during weekly structuring of production program),
- certainties that the stocks intended for the production process are actually available (material, staff, information, standards, layout, material flow, etc.),
- setting of clear productions and supporting processes for selected e-technology with regard to the allocation of responsibilities of specific staff (alternative for each shift individual responsible person with clear own e-code in information system),
- readiness of actual dates on daily basis for production planning in information system (motivated man has all necessary information available in right structured information system, he doesn't need manually or with big time wastes looking for all necessary dates),
- adequate working conditions by workplace for seamless realization of production planning and control (availability of databases, knowledge of performance and technological parameters by e-machines, standards for e-oriented production planning and control, software enabled flexible production planning and control in real time, feedback from unavailable machine capacity in information system just in time),
- proper allocation of competencies and responsibilities by staff linked in a process planning and control network,

- possibility (competency) to influence selected parameters of e-technologies by customer requirements in real working day (in cooperation with IT-engineer),
- real feedback from workplaces about realized production losses in information system (realized production amount, re-work pieces, re-typing times, cycle times, maintenance times, etc.),
- competency to stop the production process by the system failure and active corrections in process management system as a preventive action,
- possibility of self-realization by planning – realization – control of production system in according to balancing the performance management system and innovations given for higher profitability of this performance management system.

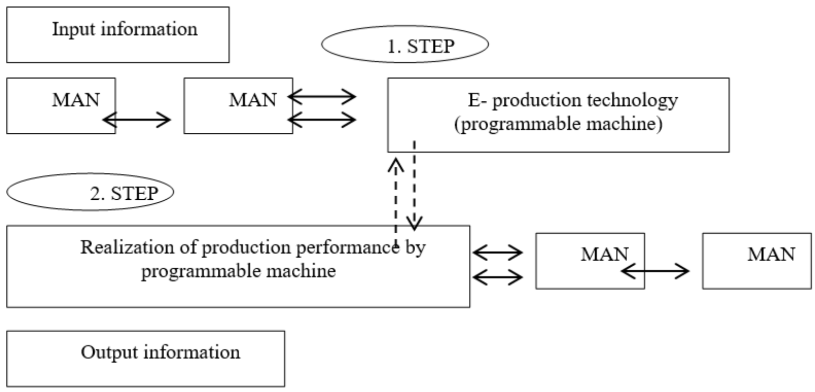

Figure 1: Core structure of managerial model of performance systems (source: author)

2. INDUSTRIAL ENGINEER – DIGITIZED PROCESS DEVELOPMENT

Key interests of scientific research were derivatives from the individual interview, realized during 2016-2017 in 300 industrial companies in Czech and Slovak Republic. Interest groups were production directors, masters, supervisor, team leaders, machine labour. Formulation of core research hypothesis for the identification of production process digital literacy by employment:
a) Interoperability - cyber-physical systems link each other's human activities to compact, intelligent processes that communicate with each other on a digital basis
b) Virtualization - by sharing virtual copies of production systems, online digital sensors create data that can be used in virtual 3D planning and control simulation models, while providing data for 3D product prints in real-world production
c) Decentralization of process management - the ability of cyber-physical systems to make real-time decision making in the form of a digital manager
d) Real-time data availability of the digital manager - the definition of services claimed by manufacturing processes and systems provides full electronic support for on-line production process management
e) Modularity - Flexible adaptation of smart plants and smart manufacturing technologies to change product

Under “human activities” we understand all activities connected with preparation of production plan – realization of production order by workplace – expedition of order to customer with strong cooperation with computer aided production system. “Human” should know the rules and standards of communication with computers and digitized machines.

Table 1: Core tasks realized by employment in digitized technologies (source: author)

Specification of production order	Setting up and digitizing of identification codes for product parts and relevant types of production operations Creating digital bindings of the "product - manufacturing process" Providing comprehensive digital inputs and outputs
Production portfolio management by production cell	Identification, setting up and standardization of the collaborative platform for the digitally controlled manufacturing process Flexible simulation of the production process Database of availability and performance parameters of production technologies
Production planning and scheduling	Setting up and standardizing the platform and procedures for digital decision making Personalization / Setting up the e-carrier of digital links Install and manage cloud storage of production data
Flexible job organization	Multi-level, digitally-organized production scheduling in real time Organization and administration of data analytics in real time Creating online error identification and fault elimination
Production process realization	Online Workplace Performance Monitoring Scheme Optimizing material and information flows Digital management of production processes
Customer satisfaction	Setting up a digital protocol for testing the quality of the manufactured product, the production process being carried out Creation of digitally controlled process improvement systems

Finally, we can formulate the definition of digital literacy as follows: digital literacy is the ability to use information and communication technologies to find, evaluate, create, and communicate information, requiring both cognitive and technical skills. The employee Is able to use diverse technologies appropriately and effectively to retrieve information, interpret results, and judge the quality of that information; next to understands the relationship between technology, life-long learning, personal privacy, and stewardship of information a uses these skills and the appropriate technology to communicate and collaborate with peers, colleagues, family, and on occasion, the general public.

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Ergonomics at non-productive areas, Nordic Questionnaire, ErgoMap, ErgoModel

Miroslava KRAMÁROVÁ*, Ľuboslav DULINA**, Ivana ČECHOVÁ***

THE MODEL OF ERGONOMICS AT NON-PRODUCTIVE AREAS IN INDUSTRIAL FACTORIES

Abstract

The article provides information about proposed model of ergonomics that evaluates the workers workload in selected non-production areas of the industrial companies (enterprise logistics, maintenance, administration). The evaluation in the model of ergonomics based on current detections in connection with occupational diseases and analysis of the current situation through a research conducted by Nordic Questionnaire.

1. INTRODUCTION

In the year 2017, 354 cases of occupational diseases reported in the Slovak Republic, with 58.5 % of the total number for man workers. Based on the analysis of reported occupational diseases in relation to categorization of work, 222 newly diagnosed diseases were reported in the category of work classified as non-risk 1 st and 2 nd category, which represented 62.67 %. These data confirm the current need for complete health care also for workers assigned to non-risk categories of work in terms of categorizing health risks. The activities of workers in the non-production areas of the companies are those that are included in the above-mentioned categories of work and therefore there are suppositions of no existing workers' health hazards.

2. ANALYSIS OF THE CURRENT STATE BY USING NQ

It is not possible to obtain information about the workers difficulties of work-related musculoskeletal system from the currently available occupational diseases detection until such difficulties can be described as occupational diseases based on a list of occupational diseases.

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In addition, there are not available information or statistical researches about the difficulties of workers body parts in non-productive areas of the factories. For this reason, a modified Nordic Questionnaire Questionnaire use to analyze the subjective feeling of workload. The data from the modified questionnaire processed based on responses of 308 workers from the industrial companies in Slovakia. It was consisted from 158 maintenance and 150 logistics workers. [1,2]

2.1 Analysis of Nordic Questionnaire results in relation to logistics workers

The largest share of work performed was identified in the seating position (up to 76.90%) in the workers operating the forklift. In the case of packing and storage workers was identified the increased share of work performed in the working position standing. From the point of view of the employees structure, it can be concluded that the logistics work is performed in the same way by men (in the case of questionnaire survey up to 83 %) and with a lower proportion of women like in case of maintenance.

From the NQ questionnaires result, from the point of view of the subjective assessment of the load, the logistics workers feel the most burdening factors belonging to the work environment group and the organization of the workplace. We can concluded from the results that for all four groups of logistics activities, the most burdensome factors are sudden overheating in certain working positions, excessive cold or heat and long-term work in the same working positions (standing, sitting, bending, etc.).

The greatest overall percentage of difficulties in the supportive system was identified for storage workers. From the point of view of difficulties in individual parts of the body for logistics workers in general, the greatest part of the difficulties can observed in the lower part of the back. Subsequently, there were descending disorders in the area of the neck, upper back, knees, feet, hands and wrists, shoulders, head, hip joints, elbows and ankles.

2.2 Analysis of Nordic Questionnaire results in relation to maintenance workers

The subjective response analysis of the workers to the burden reflects the difficulties of the support and movement system of men's workers until the age of 59. The reason for this is that only 3.23% of responses from male workers over the age of 60 obtained through questionnaire research, because we are already talking about the retirement age of workers.

The main predominant working position is standing in the case of maintenance workers, or alternate due to the working in seating and sitting positions. Only 0.6 % of all workers mentioned the prevailing seating working position. On this basis, it can concluded that the working position in the seating cannot considered as a typical working position for maintenance workers, which could assumed.

From the next part of the modified Nordic Questionnaire, it is possible to obtain information on the degree of the maintenance workers load defined by the load factors (situations). All defined factors have rated by the workers with the appropriate degree of risk and there is possible see that, as a moderate load maintenance workers perceive work in an uncomfortable working position, a sudden overload in some work activities, excessive noise, insufficient working space, inappropriate microclimate conditions, lifting, pulling heavy objects.

Based on the results obtained through the Nordic Questionnaires, it can concluded that most maintenance workers feel the same difficulties in the upper and lower back, knee, neck and foot areas.

3. DESIGN OF THE ERGONOMICS MODEL

Before start of the project, respectively application of the ergonomics model, it is appropriate to know the external influences and limitations that effect on the implementation of the proposed solution. These are external influences such as current legislative requirements, workers' difficulties with supportive movement system, occupational diseases, technical limitations and others. When external influences are known, it is possible to begin evaluating the proposed ergonomics model, which consists of three main parts (fig.1):

- ErgoFlow,
- ErgoMap,
- ErgoModel.

ErgoFlow is the recommended methodology of the ergonomics model for assessing the burden on selected non-productive areas of workers, which consists of a sequence of steps. These needs are implement in a coherent system of evaluation of the physical, mental and sensory load of the employees of selected non-productive areas in the company. The result of ErgoFlow is the constantly repeating cycle of improving ergonomics and eliminating the workload.

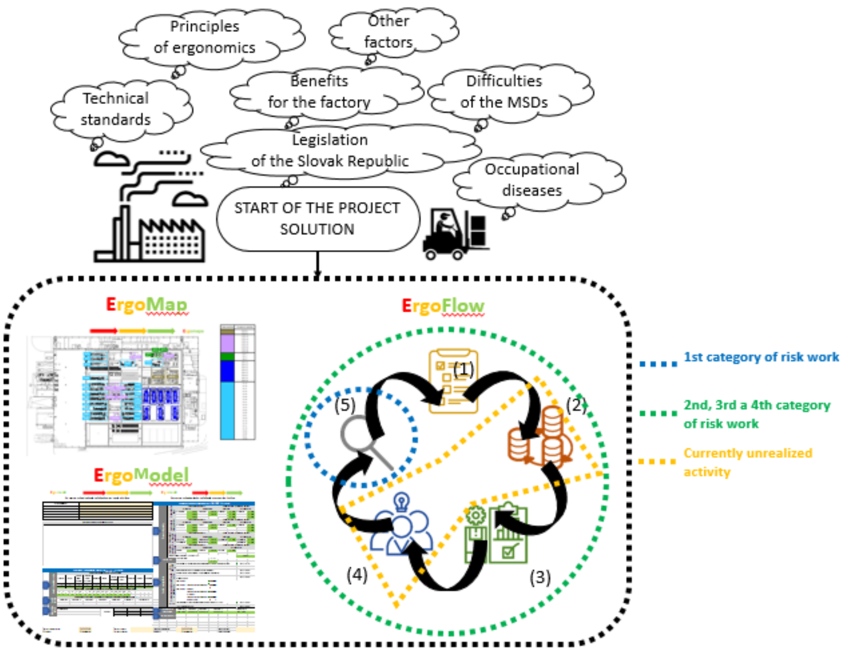

Fig. 1 Visualization of the ergonomics model [source: author]

Another part of the ergonomics model is **ErgoMap**, which serves to analyze and process input data into the cards of the risk groups of the load and associated potential risk activities. ErgoMap serves as a tool for quickly identifying potential risk activities, which can confirmed or refuted through another group of steps of the ergonomics model. Identified potentially hazardous activities in the Ergomap environment can evaluated through the first and second level tools that are part of the **ErgoModel**. The results of the available ErgoModel tools based on technical standards, legislation, research and research by the author are linked to the ErgoModel final report. [3]

4. CONCLUSION

In the case of non-productive areas in industrial factories, such as enterprise logistics, maintenance or administration, the situation is rather exceptional when these work activities are classified into a higher category of risk work (3 rd or 4 th category).
This is a major problem at present, especially for the prevention of occupational diseases or work-related health problems. The reason is that the majority of employers, in the case of the inclusion of work activities in the 1 st or 2 nd category of risk work considers that if work activities do not exceed the set limits they are not risky, but this is not entirely true. One way to prevent difficulties respectively occupational diseases, in defined non-productive areas, is the use of an ergonomics model for the purpose of a comprehensive assessment of occupational activities. The proposed ergonomics model presents a system view of the assessment of predominant load components in defined working groups, which allows detection of potential hazardous activities in order to minimize workers' health hazards.

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Simio simulation software, Health Care Systems, Agent Based Simulation

Ladislav KRKOŠKA*, Milan GREGOR**

THE AGENT BASED SIMULATION FRAMEWORK FOR SIMULATING HEALTHCARE FACILITIES

Abstract

Design of simulation framework architecture is dealt with the SHFAOF study. The aim of the SHFAOF study is to design and implement a superstructure agent-oriented simulation framework to assist in the development of detailed and simple scalable Healthcare Facilities simulation models. This specialized framework is proposed because there are standards of healthcare procedures, healthcare standards, the categorization of DRG medical services, and also based on the experience of the previously used DES in the Healthcare Facility, have been drafted in healthcare.

1. INTRODUCTION

The design and creation of Agent-based simulation (ABS) is a relatively lengthy process. However, using this form of the designing some elements of the simulation environment, can be achieved either mimic human behaviour, or get a synergistic effect of cooperation and self-optimization in the model environment, for searching area of possible solutions etc. [1]. By creating the convenient environment and objects, can be dramatically reduced the time for creation of ABS model. In comparison with conventional approaches, such as Discrete-event simulation (DES), it would be even much faster. Not to mention, that the examination process in healthcare facilities is strongly influenced and regulated by the humans themselves (medics and patients). That is very difficult and imprecise to emulate by traditional approaches. [2, 3]

2. THE FRAMEWORK SHFAOF

After comparing multiple MAS developing platforms, we have come to the conclusion that the most appropriate category for our needs is Agent-based simulators. In the disertation thesis we compared the two most potential candidates Simio and AnyLogic. The comparison came out as the most suitable is Simio, in the case that the full version of the product is available. This chapter describes the SHFAOF, which is realized in the Simio.

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2.1. The concept of primary functions of basic objects classes of SHFAOF

The selected object approach to the designing the agent-oriented simulation framework SHFAOF defines the basic classes of objects of the proposed concept realization. Instancing from the basic classes of objects can specify its own functions in the system. The proposed primary functions of the objects are described in Fig.1.

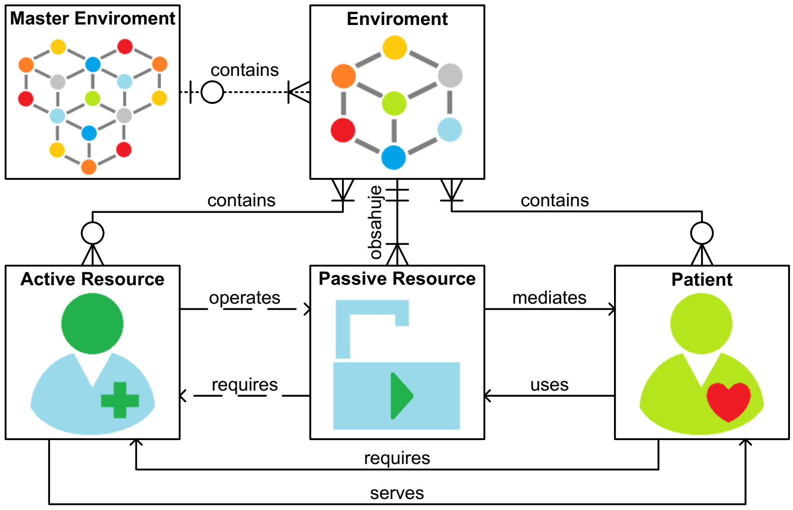

Fig.1. EDR diagram of relationships between the basic classes of SHFAOF objects

However, in the designing of communication mechanisms, it is necessary to count with that SHFAOF is not a search for optimal management of Healthcare Facility, but a credible imitation of actual interactions between its individual elements.

2.2. The hierarchical concept of SHFAOF library objects

The hierarchical structure of the categorization of SHFAOF library objects and their composition are divided into five basic levels. Therefore, the hierarchical level of the healthcare model includes, in addition to the Master Environment, the Patient Generator, and Patient Output, regardless of whether or not the top model is the Master Environment or Environment. As far as modelling points are concerned, they are ranked as a model assistant. This approach of one and only Patient Generator is chosen to centralize data into the highest hierarchical model. It also allows unambiguous monitoring and evaluation of patient flow between departments. The hierarchical level of sub-models is the second level of model division. Sub-models are models that contain the Main Environment and therefore the Environment. Each of the Environment objects, each of the sub-models can contain three basic classes of objects: Active Resource, Passive Resource, and Patient.

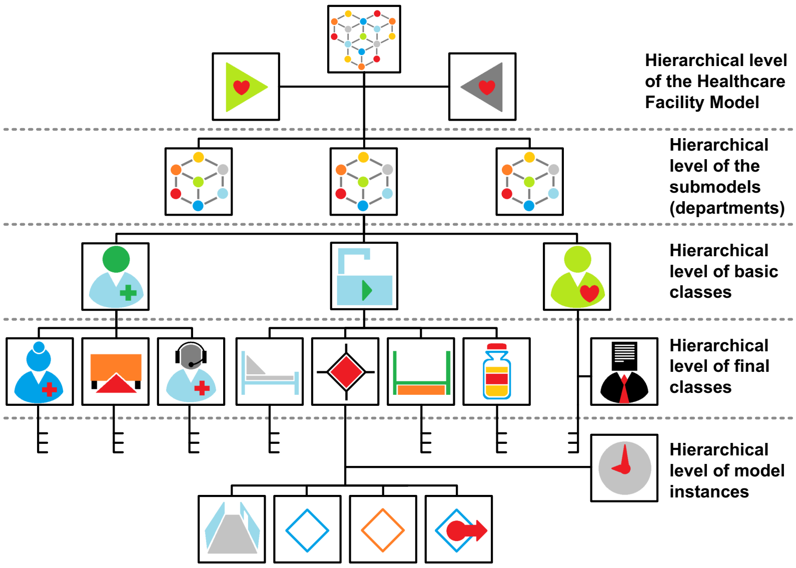

Fig.2. The hierarchical structure of classifying SHFAOF library objects

In Tab.1. is a description of Fig.2. containing object names, the used Simio standard simulation source object types, and a possible use case of the object to create the best candidate for service in the simulation model.

Tab.1. Brief description of designed SHFAOF library objects

ICON	OBJECT NAME SIMIO OBJECT TYPE	USE	ICON	OBJECT NAME SIMIO OBJECT TYPE	USE
	Master Enviroment Model	Connecting Enviroments		AGV Wehicle	Distributing medical material
	Enviroment SubModel	Creating department model		WorkplaceHF Workplace	Place of healthcare service
	Patients Generator Source	Producing different patient types		AGV Platform Entity	Cumullating medical material
	Patients Exit Sink	Deletion of patients		Medical material Element	Monitoring medical material consumption
	Active Resource Main class, Agent	Instanting dynamic resources		Spatial Element Main class	Instanting spatial elements
	Passive Resource Main class, Agent	Instanting other resources		Corridor Path	Representation of the movement free space
	Patient Model Entity, Agent	Instanting patients		NodeHF Basic Node	Connecting and crossing Corridors
	Diagnose Agent Token	Patient´s delegate negotiation		AGV Station Transfer Node	Loading, unloading, charging AGV
	Healthcare Staff Worker	Instanting different healthcare workers		ExternalHF External Node	Node of departments connection
	External Healthcare Resource	Instanting external healthcare resources		Waitroom Transfer Node	Queue of waiting patients

Instances of basic classes can get the final class of objects. Subsequent instances from the final classes are given objects of model instances, which in the simulation run will form their duplicates, i.e. independent objects with identical values of the input variables. In the simulation model, the object library will contain the final class of objects or their instance. A special case is object Patient, whose final class is at the same time a basic class, whose assistant is Diagnose Agent. In Tab.1. are objects that are highlighted in yellow-green color, that will be used by the user of the simulation framework (analyst). Other objects serve as a help in simulating the model or creating final objects.

3. CONCLUSION

Successful deployment of intelligent agents in mimicking health care systems has attracted many researchers with the emerging wave of software engineering paradigms in more complex computer simulation applications. The main factor of success here was the natural mapping and imitation of real problems and limiting factors of healthcare system operations into cyberspace. Multi-agent systems (MAS) are a natural choice for a dynamic and open environment characterized by heterogeneity with a multitude of interactions, gradual planning, and sometimes spontaneous changing dynamic environments with great human factors and rapidly increasing data volumes in various forms. The dynamics of complex systems, such as a Healthcare Facilities, can only be studied using the theory of complexity and simulation tools that allow the use of intelligent agents and multi-agent approach. The designed simulation framework in the form of the objects and agents library for simulating processes of Healthcare Facilities is already in a usable form, its full deployment and use to analyse and improve processes in Healthcare may take some time. An important factor is the processing of data for healthcare catalogues so that this data can be disposed of in analytical studies for Healthcare Facilities. In case of filling in the data of the DRG health care services and its addition to the collection of data analysis of individual healthcare performances. So that, it would be possible to compare the efficiency of providing health care services by the Healthcare Facility or with what efficiency they manipulate with the medical material and resources.

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Factory Twin, Digital Twin of Factory, Factory of the Future, Smart Connected Logistics

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ADVANCEMENT FROM DIGITAL TWIN TO FACTORY TWIN

Abstract

The paper introduces information about the Digital Twin concept in the context of a comparison with the Factory Twin solution, developed within the framework of Smart Factories and Industry 4.0, while showcasing the details on practical examples.

1. INTRODUCTION

The last two decades were characterized by the exponential growth of technological innovation. The new, massive wave of innovation in the industry, also referred to as the fourth industrial revolution, is primarily based on the use of advanced information and communication technologies (ITCs), automation and robotization across all areas of industry.

Since the nineteen-eighties, worldwide capital flows have been directed mainly to the countries with comparably low labour costs. Globalization has facilitated and accelerated the spreading of new technologies, approaches and ideas. The omnipresent rapid technological advancement forces companies to expeditiously change their production environment. If businesses want to maintain their competitiveness, they must think fast, anticipate what the future holds, dynamically change their business strategies accordingly, and implement necessary changes straight away. Only those who can keep it up perpetually, can become successful in the long run.

The present, dynamic and turbulent world markets require major changes in factory design and organization. That is why today, with ever-growing frequency, we talk about the Factories of the Future (FoF), that should ensure sustainable competitiveness. The journey to achieve the challenging goals will not be easy, and every business will have to go through it at its own pace. Factory Twin, the solution currently being developed by the Central European Institute of Technology (CEIT) in cooperation with the University of Zilina, proposed and described in this paper, is aimed to help gradually and systematically build a modern factory environment in line with the standards of Industry 4.0.

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1.1 Digital Twin

Digital Twin in the most general and the most widely used meaning refers to a digital replica of a physical asset, including its logical structure, internal processes and its design.
To explain the concept of Digital Twin in more detail, a practical example from an industrial environment will be introduced – an example that represents the idea of Digital Twin in quite a broad range of functionality, and well enough to show its most important aspects.
An AGV device, a mobile robotic system, continuously developed and implemented by CEIT, working within the intelligent logistics platform, is a great example of a smart connected product that can definitely be referred to as the Digital Twin. The AGV communicates with its digital representation (twin) within its higher-level control environment to continuously improve the efficiency of its smart autonomous actions, furthermore, it is able to communicate with other objects' digital twins, to improve mutual coordination.
The system uses automatic object position identification, it can communicate with and control other peripheral devices such as stationary and dynamic conveyors and other objects within its environment. The system also includes its own monitoring and control system, linked to the system of production planning and control, to be able to react in real time to the actual requirements of the production system that it serves.
This system consists of various elements, each of which has its hardware part (physically deployed in the real system) and its software part that creates the so called Digital Twin of the object (usually located in the cloud). In practice it means that every smart connected element of the system has its own virtual (digital) representation – a digital twin. The logistics system then operates in both the real factory and the virtual environment, where it is represented by agents. This duality enables autonomous optimization of the logistic system's operation in its virtual model, based on prediction and simulation, and then allows the decisions to be transfered into the real environment via an agent management system.

1.2 Factory Twin

Digital Twin represents a physical device and its behaviour. A production system is created by groups of physical devices, the social system and the production management system.
Device operation in the sense of Digital Twin is a concept that facilitates the creation of a superior system, able to make sense of all the separate smart objects within the system – a comprehensive enterprise solution that is currently being developed and implemented under cooperation of CEIT and EdgeCom, holding the name **Factory Twin**. This system then allows for all-way communication, smart control, continuous improvement and autonomous operation of all respective objects within the factory, in one complex virtual environment, therefore being able to bring a significant synergic effect. Such a solution's sole purpose is to create transparent and strong base for swift and easy development of Smart Factories.
The way we comprehend and explain a Smart Factory is as a symbiotic interconnection and cooperation of the three main parts: **Real Factory, Digital Factory, Virtual Factory** (Fig. 2a). The **Digital Factory** is basically a 3D digital representation of a **Real Factory**, that allows for quick and very efficient factory design or optimization proposal and verification.
Data gathered from the Real Factory through the ubiquitous IoT (Internet of Things) technology (via sensors and communication networks) forms the basis of the **Virtual Factory**, which is actually the data representation of the real factory operation and with the support of artificial intelligence it is a prerequisite for autonomous control and self-optimization of the Factory Twin

in the first step and of the Real Factory afterwards, fully autonomously of course. The symbiosis of the real, digital and virtual factories is represented in Factory Twin, which has become inseparably interlinked with the term Factory of the Future.

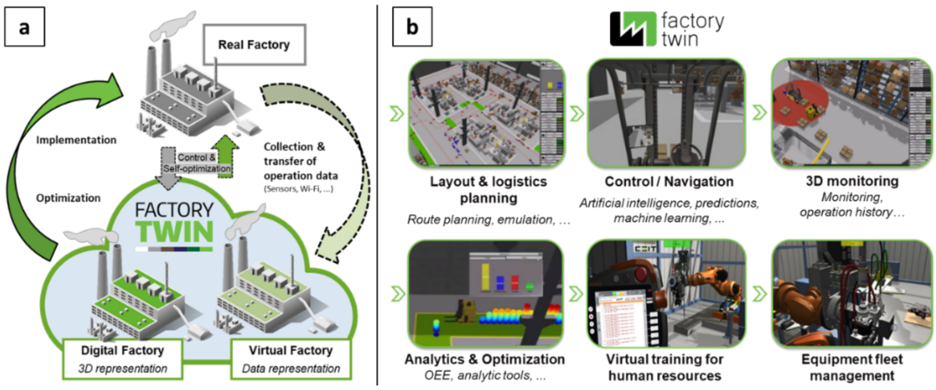

Fig. 2 a) The three parts of Smart Factory, b) Basic Factory Twin functions [1]

The Factory Twin solution builds on the use of RTLS (Real Time Locating System) and various other sensors, allowing to gather data in real time, and transfer it to the cloud or to a local database. The RTLS system used in this solution is based on Ultra-Wide Band (UWB) technology, that can track real-time location of objects, equipped with tags while ensuring a guaranteed precision of ± half a meter.

The Factory Twin solution builds on the use of a sensory network (leveraging RTLS and other sensors) and the revolutionary ELLA virtual development platform (including 3D physics, visual programming, and more) and provides a wide set of functions, some of which are shown in Fig. 2b. The most basic functionality is 3D monitoring, which gives the basis for further analytic tools for detailed inspection and analysis of the operation of production and logistic system which brings an enormous, never before seen, potential for optimization of the whole system based on facts gathered via the aforementioned sensory network. It further provides the ability to plan production and logistics layouts and processes, offers evaluation of the proposals via emulation and grants the capability to directly use the planned processes in control of automatic and in navigation of manual logistics.

A special part of this solution is the virtual training system, that enables employee training in the virtual environment of the Digital Twin of the Factory (Factory Twin), which directly correlates with the real factory's environment. Furthermore, this system allows to train in a future state of the production system, that has been proposed, but is not yet implemented.

The standard workflow of Factory Twin can be better explained by the optimization circle shown in Fig. 3a. The process starts off with a planning phase (and its support tools), where proposals for the improvement of the production environment are created, so they can be further analysed with support of dynamic simulation. After the optimal scenario is chosen, the virtual training of the workforce starts even before physical implementation of the changes. When the changes to the system are physically implemented, Factory Twin offers tools for the control and operation of the production and logistics system, with a capability to self-optimize. When the system is operational, the monitoring and fact-based analysis comes into place, bringing digital data to the planning process, therefore closing the optimization circle.

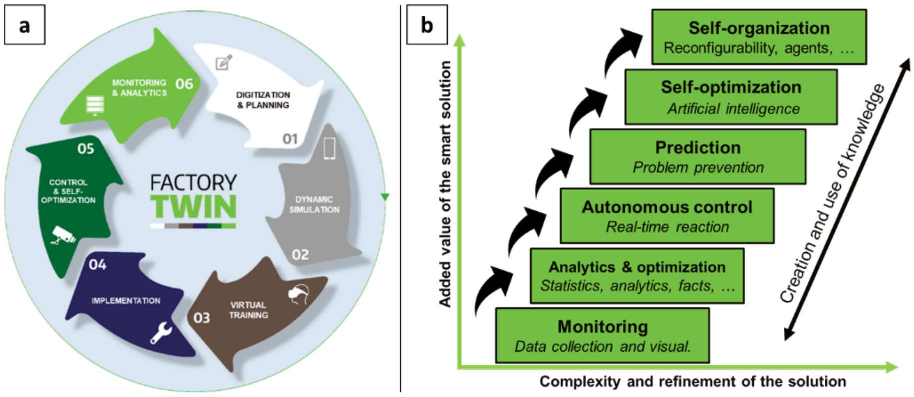

Fig. 3 a) Factory Twin Optimization Circle, b) Smart Solution Stairway

Fig. 3b shows the Smart Solution Stairway, that illustrates the steps and levels of sophistication of a solution, from basic monitoring, up to full automation and man-like intelligence and autonomy.

Only a by fulfilling the standards of Industry 4.0 can a system reach the top part of the illustration and become near to the theoretically idealistic Smart Connected Solution. Factory Twin already possesses elements of all levels of the Smart Solution Stairway, while its development team is currently focusing most of its efforts onto the top three steps of becoming the ideal of smart technology. [1]

2. CONCLUSION

The nature works as a complex, self-organized, holonic system. Even a human is made up of small, autonomous units – holons – which work together to create larger, autonomous, complex entities, which form a complex holonic system – a human being. Biological systems represent the most efficient and powerful systems that humanity knows today. These systems serve the scientists as models in creating nature-inspired "artificial" mechanisms for manufacturing. New breakthrough technologies have begun the transformation of today's production. We must perceive the future production and its organization in a new light. Trends like Industry 4.0 and IoT, concepts like Digital Twin or solutions such as Factory Twin, allow businesses to gain a competitive advantage and be one step ahead on the way to the future.

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Bin picking, Robot, Manipulation, Automation

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ROBOTIC BIN PICKING IN PRACTISE

Abstract

Serial production nowadays carries many monotone operations necessary for the mass production. These operations may be automated or they are assigned for automation costingness - financial means performed by operator. Products handling into machines, where the given product evaluation is performed, is an example of an operation that can be effectively and economically managed today through the implementation of the automation process, however the technology integration is not yet practically mapped.

1. INTRODUCTION

The monotonous work of operators in the serial production is nowadays the part of the production processes of large-scale suppliers not only in the automotive industry, but it is also the image of the entire industry worldwide. Operations such as manipulation of parts prior to their evaluation, subsequent manipulation after the termination of manufacturing operation are bringing into the production times and operations that are not projected in the final product price. These are called unproductive times. Naturally, they are projected in the final product price. However, these are costs that have tremendous potential for valuation. The final price can either be reduced (pressure on competition and the profitability from the new projects), or in already running projects, it is possible to reduce production costs and consequently to increase the profit on the production article. One of the options how to remove or completely eliminate manipulation time is the introduction of bin-picking technology. Todays advanced 3D camera systems based on a scanned image are able to detect undirected products in product bins. These products are consequently identified and according to different strategies determined which part according to the robot is to be chosen. The issue of bin-picking is not yet documented and there is no comprehensive guide to the integration and implementation of this technology. The big impact on the bin-picking technology is mainly its return.

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2. INTEGRATION SUITABILITY

The return of every investment is a guiding factor for commissioning any new technology. When calculating and determining the application suitability, it is necessary to know the product life and the share of the product price by the operation itself. The integration process mainly eliminates the monotonous work of one operator who loads the part into the machine and consequently unloads it after the operation. All the factors that influence the removal of this operation should be taken into account. This is not only the operator's salary, but also the operator's ergonomics. If the operation is no ergonomic, what the majority of such operation is, (because the spine overload and the carpal tunnel overload on the hands are concerned) it is also necessary to consider the necessity of exchanging operators, increasing payments for insurance, and similarly.

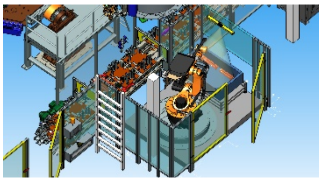

Fig.1. Simulation of bin picking for real integration

3. INTEGRATION

The integration itself consists of several critical points that affect its success. It issues mainly from the choice of a suitable camera system, the grip structure and the robot's placement itself against the product bin and the camera.

3.1 Camera System

It exist number of technologies for bin-picking integration with a six-axis robotic manipulator which are able today to reliably work not only in the lab, but also in the practical integration. The high-quality camera system and its features are crucial for accurate parts detection. When selecting the camera system, it is necessary to take into account many aspects that can influence the given integration. First of all, it is the size of the parts and their placement in the product bin. Consequently, the lighting conditions and the OEE that needs to be achieved are influencing the integration. The size of the parts which can be integrated by bin picking is fundamental in term of the camera system choice, from the view of camera resolution. As long as are small parts placed in a large product bin, the system may fail due to the fact that the part is insufficiently identified. The camera resolution causes that the real size of one pixel scanned by the camera is high and consequently the scanned image is inadequate. Therefore it is necessary to evaluate whether the integration is possible. And also fundamental becomes the algorithm for identifying parts that can, based on a scanned image, identify the part’s orientation in 6 axes and calculate the grip point for the correct grip and removal of the part from the product bin. Light conditions affect integration itself sorely. However, unlike the foregoing aspect, this can be solved with various encryption and emplacement of the camera system within the sunlight reach. The sunlight causes the biggest problem during the integration of the camera systems. One of the

most effective steps is to "burn" the scanned subject with a strong light that creates the consistent conditions, either during the day or during the night.
No device works with 100% efficiency. It is also necessary to take into account the suitability of integration in terms of the success of the parts selection. There is a difference in OEE when we talk about the inability to detect parts in the product bin with 2000 pieces compared to 50 pieces. The impact of efficiency is clear in this case.

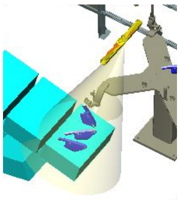

Fig.2. Camera scanning volume from simulation of the process

3.2 Gripper

The correct grip construction significantly influences the success of bin picking commissioning. Currently, a various gripping possibilities are used. Grip may be mechanical, magnetic or pneumatic. Each of these variants has its pluses and minuses.
Mechanical grip is suitable when the certain part has a section which can be safely used and always detected during the scanning with a camera system. It is ideally used for rotary and symmetrical parts, such as shafts, forged pieces.

Fig.3. Typically rotational part for using mechanical gripper

Magnetic grippers can be an effective grip for the parts that have dirtiness on themselves. However, the correct calculation of the magnet force needs to be done. Because there is a risk, during the removal of certain part, to remove the bunch of several parts instead of just one. This can lead to insufficient positioning in the output.
Pneumatic grippers are used as vacuum cups for parts that are mostly smaller in size and have suitable surfaces for cups leech. This technique ensures some flexibility and volition for the output part positioning.

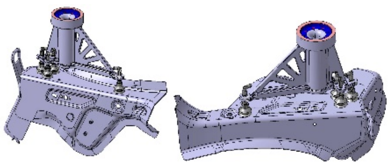

Fig.4. Gripper with vacuum cups suitable for variety positions of part

3.3 Robot

Bin-picking can be at present integrated into each robot brand-names and sizes. The important factor is the correct configuration and disposition of the robot with regard to the product bin placement. The robot has its own control and its own operating space. These two controls must be connected to the control of the camera system. Own control has to gain information about the final robot position and what route to choose from the camera control. Because the camera sends to the robot the required co-ordinates, where the robot can pick up a part. Robust camera systems do not consider just the end point, but they also re-count technique how to get there considering the surroundings, and possibly collision not only with the part, but also with the product bin, or with itself.
The interconnection of the co-ordinate systems is very important as long as they must be equal. If they split, there would be a deviation that could cause a collision or inadequate grip of the part. These coordinate systems should be calibrated at certain time intervals to avoid errors.

4. CONCLUSION

Bin picking is a new technology which its integration is already possible and which possess the successful commissioning. However, it is a complex technology that can be influenced by many factors. First of all, it is necessary to take into account the financial impact on the final product price and the product life cycle. Consequently, when it comes to integration itself, a large number of structural, simulation, and program tasks need to be solved. Selecting a suitable camera system is also crucial for the future and sustainability of the technology.

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Simulation software, Discrete optimization, Production scheduling

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AN INNOVATIVE SYSTEM FOR SOLVING PRODUCTION SCHEDULING PROBLEMS

Abstract

An innovative system for solving production scheduling problems is created based on data from a real production system at the level of the workshop. In the present article, there are proposals of individual modules of an innovative system with proposed communication channels that link individual elements of the object library created to solve the problem of sequential production scheduling. With the help of the created communication channels, the individual parameters of the real production system can be applied directly to the assembled model. The proposed system introduces an initial set of optimization methods that can be applied to address the sequential problem of scheduling production.

1. INTRODUCTION

An innovative system based on computer simulation and optimization methods addresses the sequential scheduling problem (JSSP) for the sake of versatility, which includes a number of manufacturing systems and also the fact that in practice we encounter a number of modifications to the scheduling problems of production. The proposed innovative system should meet the option of creating solutions for both robust manufacturing systems and smaller production systems where resources are limited. [1] The role of an innovative system is also to create workflow schedules that will not only be satisfactory for a physical production system, but will reflect the real state when processing individual tasks through its internal processes [3].

2. DESIGN OF AN INNOVATIVE PRODUCTION SCHEDULING SYSTEM

In the proposed innovative system, communication between the physical production system, management and management of the input / output data of the physical production system takes place, directly affecting the parametric model reflecting the behavior of the physical manufacturing system. The innovative system design concept is illustrated in figure 1, which also lists the individual modules as well as the information flow between modules. The

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information flow is represented by solid black lines with arrows at their ends according to the flow of information and the individual modules represent dashed lines with color difference.

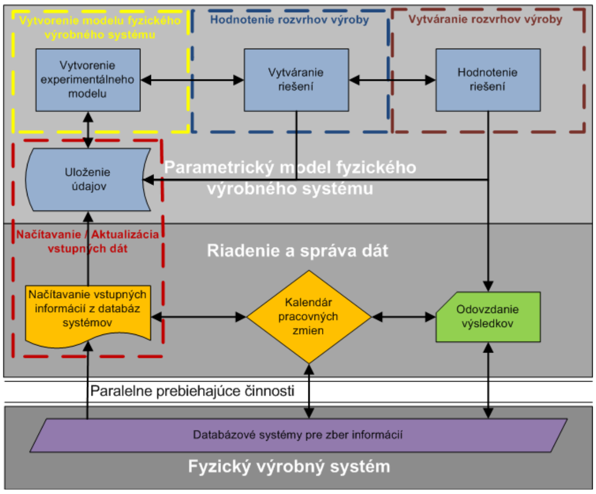

Fig.1. Diagram of individual modules of the innovative system

2.1 A detailed description of each step of the innovative system

The first step of the proposed solution is to read input data or update them, for the sake of the availability of consistent data that is necessary for the model of the physical manufacturing system. If ERP (Enterprise Resource Planning), MES (Manufacturing Execution System), or SCADA (Supervisory Control of Data Acquisition) systems are used in the production system, it is possible to draw from their databases information about the production system and periodically update them to obtain more accurate estimates of emerging conditions. Updating data takes place before the production system model is initialized, due to the acquisition of consistent data from the physical production system.
The second step is to create a physical production system model that emulates the behavior of the real system. For this step, it is necessary to have enough information in the input database of the simulation software. This data enters the created model in the simulation software to create a model of a real production system. In order to create a model, it is necessary to know which data are the same or similar for each production system, and to create a model corresponding to reality from these data, and the user may not have the knowledge of working in simulation software.
The third step is to create alternative solutions to production schedules. It is important not only to use the model of the physical production system and the data obtained from the physical production system, but also other data, such as the production orders entering the production system. This information is initialized directly in the production system model, after which various production schedule solutions are created according to the chosen optimization criteria. It is possible to combine the criteria together in this conceived concept in order to create permissible solutions for the production system that will have the least impact on its key indicators.

The fourth step is the evaluation of the variants of the production work schedules for the physical production system. The assessment of the model of the production system takes place according to the intended purpose function. Its role in the proposed innovative system is to select such solutions from the options of possible solutions that create appropriate conditions (determination of certainty or risk) for the physical production system. The selected possible solution is then exported for data management and management. These departments, on the basis of defined outputs from the physical production system model, are gradually releasing the tasks into the production process and thus managing processes at the level of the workshop.

2.2 Elements for creating a physical production system model

The elements for creating a physical production system model should contribute to the automatic creation of a real physical system. In the proposed innovative system for automatic modeling, we have processed a library of objects that can be used to create a physical production system model with one mouse click. The key objects of the created library and their modifications are:

1. Input of production orders
2. Manufacturing equipment
3. Handling units
4. Products
5. Decision-making rules
6. Statistical evaluation

In the proposed innovative system, an iterative (step-by-step) approach to creating a physical system model is used in the simulation software. With such a strategy it is possible to modulate and flexibly determine the appropriate levels of detail that are found in the physical production system.

2.3 Decision-making rules applied in an innovative system

In the automatically created physical production system model, it is an essential element for creating a workable solution to a sequential scheduling problem, due to the choice of a rule by which individual tasks from production orders are selected and allocated to production facilities. With a growing number of manufacturing facilities, as well as the tasks that the physical manufacturing system will process, a huge number of combinations of feasible solutions arise. In the most complicated cases, heuristic approaches are used to achieve a workable production scheduling solution or a healthy sedentary mind is used [2].
Optimization algorithms have also been chosen for the proposed system, which allows you to experiment with a robust, as well as a minor problem of sequential production scheduling. These optimization algorithms are:

1. Critical Ratio
2. Flow Due Date
3. Waiting Slack
4. Slack / Remaining operations
5. Operational Flow Slack per Processing Time

The decision-making rules for the proposed innovative system are designed to address the sequential problem of scheduling production to perform experiments with robust physical production systems as well as smaller production systems. The proposed system has just such rules that can be applied to address the sequential production scheduling problem while capturing the individual key time characteristics of the production orders with their respective tasks for performing all the operations based on the technological process of the product. The decision-making rules used are among the dynamic ones that derive from the current time in the computer model when the decision is made, and then update the priority of the task in order to determine the direction of the task in order not to delay the delivery of the final production order.

3. CONCLUSION

In the number of existing businesses, planning and production management are still statically taken from the perspective of dynamic testing of various risks and uncertainties. Employees in management positions do not always know tools or techniques that allow them to identify and reduce the amount of emerging risks and uncertainties in decision-making. Currently, the right decisions are considered highly topical. On the basis of a quick and correct decision, there are differences in the success of individual businesses. For this reason, the presented work is devoted to the design of a system for the support of production planning and management, depending on emerging customer requirements for the production system.
Currently, there are a number of software solutions on the market that deal with production planning and management but even though they have implemented various management strategies to capture real production conditions they often have problems because most of them lack the implementation of a simulation tool to decipher and verify variants schedule with discrete simulation elements.

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Reconfigurable Manufacturing System (RMS), Reconfigurability, Manufacturing lines

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RECONFIGURABILITY AS SOLUTION FOR CURRENT PROBLEMS OF PRODUCTION LINES

Abstract

The article provides an overview of current problems of manufacturing lines which are classified into three categories. Next part is devoted solution of these problems via core characteristics of reconfigurable manufacturing systems. Conclusion contains the suggestion for further examination of current problems manufacturing systems and opportunities for improvement.

1. INTRODUCTION

The current proposal of manufacturing lines has comprehensive structure and it is difficult problems for many enterprises. For the design of production lines is needed to consider many options and objectives for optimal result. Many studies describe academic methods for optimal solutions, but they don´t solve their feasibility for real conditions in the manufacture. This issue causes several factors as input data, the problem of multiple objectives, variability, layout, and scheduling. Input data can´t be applied to current methods because they are not able to work with the big amount of data and can provide incorrect results. Another issue is that all objectives must be evaluated simultaneously and not only in a separate order. Variability process time and scheduling of operations are rapidly rising problem in a various production environment. In the fact, this problem is caused an increased variety of manufacturing products. The offered products involve more and more parts because the customer considers customized products. Also, the global market enables a large selection of products for the customer. Therefore, all companies must focus their attention on solving the issue which relates to this change [1].

The basic problems current production lines, as well as a solution for these problems, are described in the next section. We can divide problems of current production lines into three categories:

- Variability of process time.
- High-level comprehensivity of operations scheduling.
- The insufficient of responsiveness and low-level of flexibility.

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1.1 Variability of process time

The process time specification is a basic part of design and optimization, where the maximal level of this parameter shouldn't be higher than the value of cycle time. However, the value of process time depends on many criteria, which must be taken into consideration. A typical example is increased or decrease process time as a result of machine breakdowns, comprehensive of operations and the level of automatization. In the case of manual assembly lines, the task time is constant only when workers are qualified and motivated. On the other, hand in the case more advanced machines and robots have task time permanently and constant speed.

1.2 High-level comprehensivity of operations scheduling

The comprehensive of operations is a significant problem for scheduling of operations on the machine. Some operations have been fixed on given stations and no other operation can be added to it. The next problem is a specific set of operations which must be grouped on the same stations because isn´t possible to add or remove operation in this set. Some of the operations can be executed manually, automatically or by robots, which means that the designer must consider associative preferences between all operations on the production line. The last issue is related to the assembly or production product itself because of each product involve the various types of relations among workplaces. These constraints are often causes of increment product price and long delivery time on the market. Therefore, we must focus on a solution these problems for design manufacturing lines [1].

1.3 The insufficient of system responsiveness and low-level of flexibility

The global market offer for a customer many product variants with varied price and quality of different manufacturers. This means that company must satisfy requirements their customers as soon as a possible. If the manufacturers don´t offer their product to the market in time, they can suffer a loss. Therefore, the main objective is to minimize the total delivery time of product on the market and fast change of manufacturing configuration depending on the market. Moreover, traditional manufacturing systems can´t produce a variety of products, with changeable volume and mix, at the same system. In order to produce new products and accommodate changes in existing products, new functions must be added to the manufacturing system.

The authors of many studies introduce the basic attributes and functions for future production systems which are capable fulfill these objectives. The basic attribute for future systems is his responsiveness, where this characteristic enables manufacturing systems to quickly launch new products on the market. Furthermore, responsibility enables rapidly react and cost-effectively into change in the market, system failures and government regulations. For achieving rapidly react must the production system fulfill the basic characteristic as scalability, modularity, customization, diagnosability, convertibility, and integrability. These enabling characteristics defined for the new paradigm of the manufacturing system. This system was named as reconfigurable manufacturing system and it was defined as a system with changeable structure focused on a part family. The problems of current production line were defined in this section, where we defined three main problems for their design and optimization. The next section of this article focuses on connection abilities of this system on traditional manufacturing line problems [1, 2].

2 RECONFIGURABILITY AS A TOOL FOR PROBLEMS OF MANUFACTURING LINES

Reconfigurable manufacturing systems are based on the six core characteristics, which they aren´t important only for the future conception of systems. Introducing this characteristic into a traditional conception manufacturing system can help with current problems in many companies. In short, of time horizon is impossible, transforming every required production plant and designed this plant as reconfigurable. We should consider applying this characteristic into existing manufacturing systems gradually. That means that we should introduce in the company only attributes of reconfigurability which are necessary for solutions problems in their production plant. Therefore, we must create a particular and feasible concept for application of this characteristic.

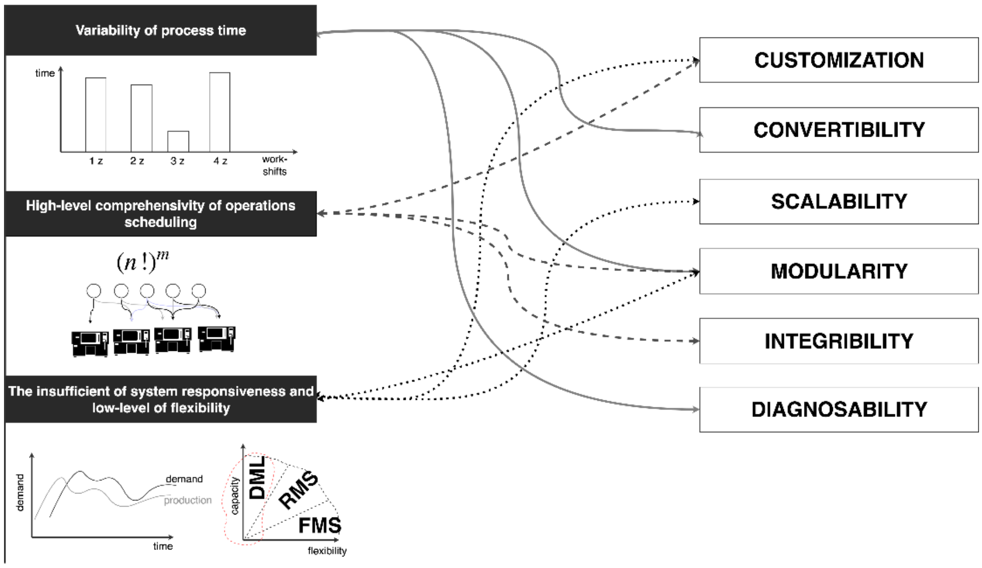

Fig. 1. The solutions to production lines problems through core characteristics of reconfigurability

As we have said, nowadays companies meet with various problems not only in the process of design but also in the production process. In the first section was described problems of manufacturing lines, now we will introduce the possibilities their connections with the characteristic of reconfigurability. The first problem is variability of the process time, this problem can be solved through convertibility, modularity, and diagnosability, as it is depicted in the figure above. Therefore, we should introduce to the systems the machine with a modular structure [2]. If is this done, modular structure of machine facilitates adapt their production capacity and function depending on variants of the product. The machine design must include likewise diagnostic module for revealing of poor product quality and systems failures. The solution to the problem with high-level comprehensivity of operations, scheduling is characteristic of customization, modularity, and integrability. The characteristic of customization enables the design of systems for the production of part families, rather than for single parts. If we reduce the amount of difference between product variants than we also reduce the options for system configurations. Ultimately, this issue may help with other problems in the manufacturing line. The existing problem with the scheduling operation is removed by integrations of modules. The integration of modules enables connect each module of systems and created of material flow for a family of products. Let us look at last problems with system responsiveness and his flexibility. The production lines are designed for the determinate capacity, but the capacity required of the product can be changed. This problem can be solved using the characteristic of scalability. The scalability enables to easily modify production capacity by adding or subtracting manufacturing resources [3]. Moreover, we can adjust the number of requires resources and reduce the capital cost of product production.

3. CONCLUSIONS

In this article was described the core characteristics and their application on manufacturing line problems. We considered the possibilities and consequences application of reconfigurability into production lines. On the base, this may be said that we must create a concept for applying this characteristic in the current factories. The companies usually can´t change the whole layout factory, but they can realize improvement with partial solutions.
Reconfigurable manufacturing systems are the future of production systems, but on the other hand, the companies face to various problems already at the present time. Therefore, we should design methods and methodologies for integrations this access to current factories. We must also connect reconfigurability with other manufacturing paradigms such as, for example, lean manufacturing, digital factory, multiagents systems and other.

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Knowledge, Performance, Performance Assessment

Lucia KOVÁČOVÁ*, Peter BUBENÍK, **

KNOWLEDGE AS A TOOL FOR INCREASING COMPANY PERFORMANCE

Abstract

Company performance increase or in other words, processes in a company determining company performance is a topic majority of companies deal with. Many companies have elaborated extensive systems and methodologies to process performance indicators, they have large investments for new devices and equipment, data processing and software equipment. However, despite this fact it is important to realize that even with a rapid growth of technologies the ability of a company to gain and select accessible information, its transformation to knowledge and company knowledge base building is an important field interlinked with performance growth. It is employees, their knowledge and the ability to use this knowledge for a company development which plays the key role in a company.

1. INTRODUCTION

Every producer makes an effort to find answers about how to gain competitive advantages in a global world. There has been a significant globalization of the world market over the past two decades and competition pressure in slowly developing markets has grown as well. Global competitors use various marketing strategies in order to reach maximum market share, reduction of local producers' impact and their control of market situation. [1] Therefore, performance is the key factor determining company competitiveness. In general, performance can be defined as a company ability to achieve necessary outputs and effects in measurable units if possible [2] or in other words, the ability to achieve set targets, evaluate introduced sources with its activity, produce profit, increase the company value and ensure future development. [3] Moreover, continuous measurement of its performance is important for a company, comparison with a competitor, evaluation of its current state in a relation to its future targets and ability to achieve these targets with current performance. In order to create a competitive advantage, it is important to use and develop these resources owned by the particular company. Besides the effort to gain knowledge, accumulate and archive it, current goal is a "delivery" of correct knowledge to right

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people in right time, use it and share effectively for the ability to successfully deal with problems, plan dynamically and decide strategically.

2. COMPANY PERFORMANCE AS KNOWLEDGE FUNCTION

In order to evaluate company performance, the company must be able to identify what is best for its future development from the existence and management's point of view. Therefore, in order to get a certain value of analysis results, they must be compared with other values. When comparing, the company must respect the extent and structure of these results.

In order to evaluate company performance, the following alternative comparisons are used:

- Comparison in time - development trends.
- Comparison with other selected companies in a given sector.
- Comparison with other quantity, standard or plan.
- Comparison based on experience.

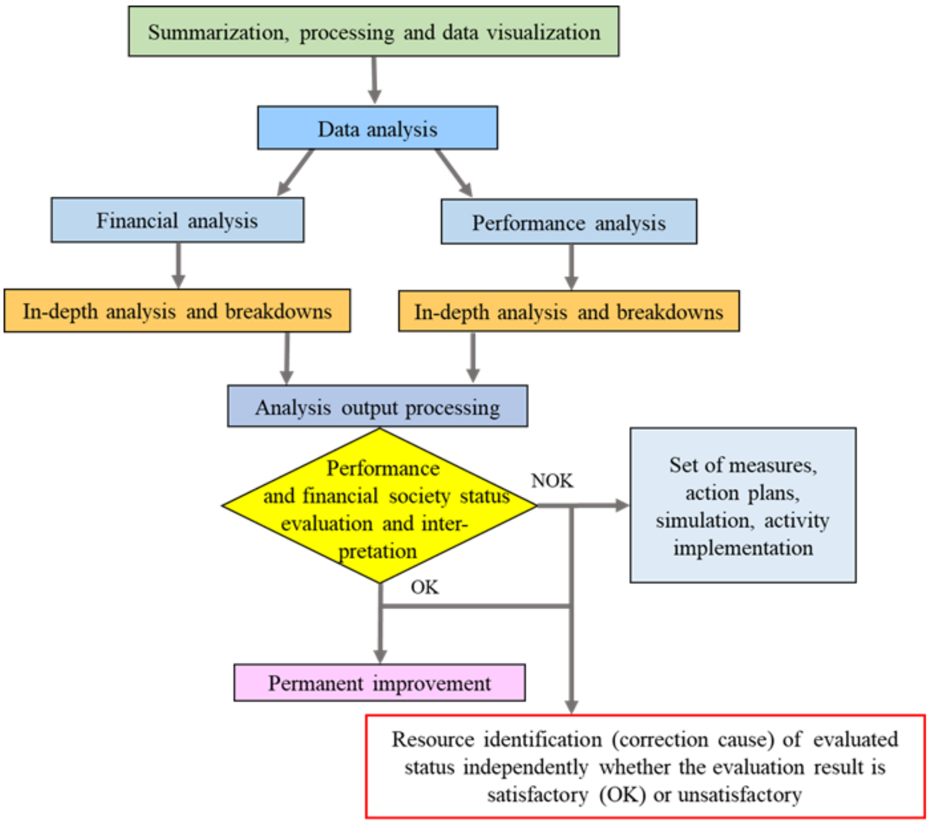

Fig.1. Performance evaluation

Company performance depends on several factors and their interaction. Apart from financial and technical resources, people, human resources and their knowledge determine company performance as well. It is not rare that company performance evaluation as knowledge function does not play a very important role, or what is missing is the recognition of this relationship importance to the detriment of financial and technical source dominance. This might lead to unsuccess when trying to reach company targets.

In the above mentioned context we could define knowledge as part of resources for:

- continual society status improvement even though it has been evaluated as satisfactory,
- correction activities to remove actual identified unfavourable situation.

In both cases of company performance evaluation result it is important to reaslise the situation:

- lack of knowledge,
- need to expand knowledge,
- ability to share knowledge in a society.
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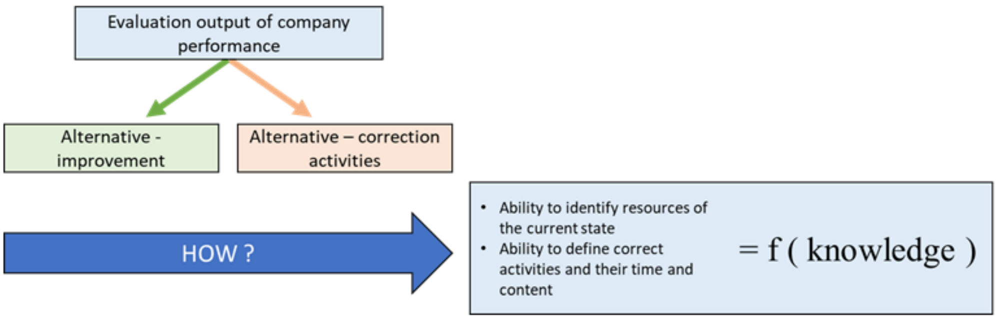

Fig.2. Activities for performance change as knowledge function

In current conditions of global economy, more and more companies are becoming aware knowledge becomes the subject of competitive advantage. Taking into account the fact, access barriers for companies to top technologies have siginificantly reduced. Way of the technologies and process organisation use in the society depends on people's knowledge in a company.

It is important to realise whether a company is aware where the source of its knowledge is and how it can work with it. The following could be assigned to important areas:

- people working in a company, their individual skills, ability to motivate employees to continue improving their knowledge, company's ability to use its employees' knowledge, mix them in teams where there will be a space for synergies of using employees' knowledge,
- archives of successful and unsuccessful solutions as an important source of activity effectiveness increase in a company, analysis of proposed solutions having regard to previous company experience, by a form of information and knowledge sharing,

- benchmarking as one of the elementary tools for society status identification in selected areas in relation with competitiveness, potential resource for activity generation in order to gain knowledge when identifying differences in relation to a compared subject,
- theory or best practices with regard to current sharing and accessibility of the latest theoretical knowledge as well as practices, experience and selected knowledge of leaders in various sectors either in a printed or electronic form, this together with benchmarking is one of the most accessible resources for company's skill development. However, it is important to realise that the mechanical solution transfering from one company does not necessarily mean a success for a beneficiary.

3. CONCLUSION

Successful company development is interlinked with skill development and skill management functioning, so called knowledge-sharing culture - culture of knowledge and information "sharing". Also, this could be defined as a willingness to share its knowledge, skills and experience and therefore enable all employees to profit from them for the benefit of the entire organisation. Moreover, another important presumption is the employee ability to understand context in which this knowledge was created, as well as the employee ability to accept this knowledge, acquire it, use it and develop it.

The basic knowledge which stands out in relation to successful knowledge management is the fact it is an iterative process. It is the process which does not finish but steadily progresses, as people's knowledge improves and develops and they are able to share it.
Company ability to identify the level of its knowledge and relation to ability to increase its performance is currently one of the key factors determining positive development. It is clear this ability will be more and more dominant in this field.

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DESIGN FOR ASSEMBLY METHODS (DFA) IN DESIGNING NEW PRODUCTS PRODUCTION PREPARATION

Abstract:

The thesis defines the concept DFA methods. There were characterized the production processes preparation in condition of mass production, trends in the methods for process design development of new products in large industrial corporations as well as their implementation in individual enterprises. Finally, the thesis determines the possibilities of given course of proceedings in the production practice application.

1. INTRODUCTION

Contemporary production processes, especially large-scale ones, are characterized by a progressive degree of automation of machining and development of cooperation services in the execution of individual components and complex, unified components of the unified components, tailored to the wishes of customers. For this reason, in managing the implementation projects for the production of new products, their design is more and more important considering their assembly technology (PdM) [4, 5, 7].

Different methods are used to evaluate the assembly technology and determine guidelines for shaping the design process due to PdM. In the automotive industry, DFA (design for assembly) methods are widely used, proposed and described for the first time by G. Boothroyd and P. Dewhurst in 1983 "Design for Assembly, A Designers Handbook" [2].

Several methods of DFA [1–5, 10] have been described in the literature – the most commonly used in manufacturing practice are presented in table I [1].

TABLE I. Summary and methodology of selected DFA methods [1, 7]

Method	Year	Inventors	Description
Lucas DFA	1980	A.H. Redford, K.G. Swift	It is based on SSM – Assembly Sequence Diagram – evaluating assembly design. It evaluates and aggregates penalty points related to product design issues
Hitachi Assimilability Evaluation Method (AEM)	1986	S. Miyagawa, T. Ohashi	Assesses the product's mountability and cost ratio to identify product design weaknesses
Boothroyd and Dewhurst	1988	G. Boothroyd, P. Dewhurst	It is based on an empirical study of the costs associated with manual or automatic assembly, including three criteria for reducing the number of components

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2. DFA METHODS FUNCTIONAL ANALYSIS

This method is used to analyse the manual and/or automatic assembly technology. The Lucas DFA rating is based on the definition of three indicators whose values are related to the relative measure of difficulty of assembly. Its purpose is to reduce the number of assembled components of the final product and to analyse assembly operations for difficulties, complexity and time consuming. The Lucas DFA functional analysis procedure is shown in fig. 1. The project is subjected to a functional analysis that evaluates the functions of the individual components and whether they are necessary [8, 9]. A feasibility study is then carried out, including analysis of the assembly and manoeuvring of the assembled components and the method of assembly itself.

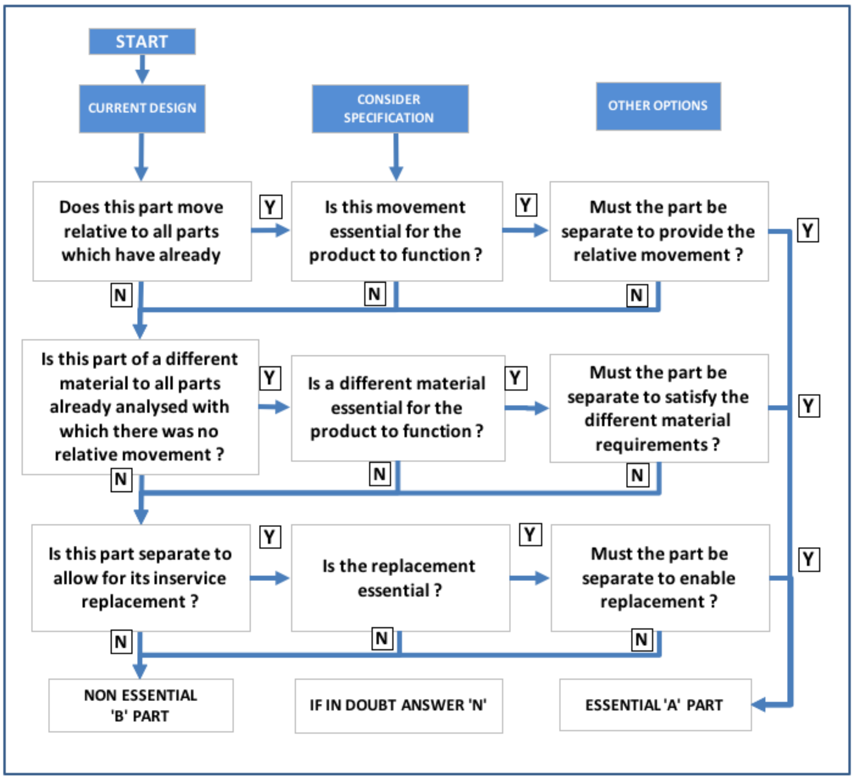

Fig. 1. Lucas DFA functional analysis scheme [9]

The W_{ep} efficiency index based on functional analysis is as follows:

$$W_{ep} = \frac{L_{kA}}{(L_{kA}+L_{kB})} \cdot 100\% \qquad (1)$$

where:

L_{kA} – number of components A (fulfilling product function),

L_{kB} – number of components B (not fulfilling product function, e.g. rivets or washers).

3. EXAMPLE

A single-stage prototype design was subjected to the Lucas DFA (fig. 1). The construction was designed on a production basis. For the accepted production conditions, the assembly process is defined. For analysed gearbox (fig. 2). each step of the assembly process was defined, the L_{kA}, L_{kB}, W_{ep}, values were calculated:

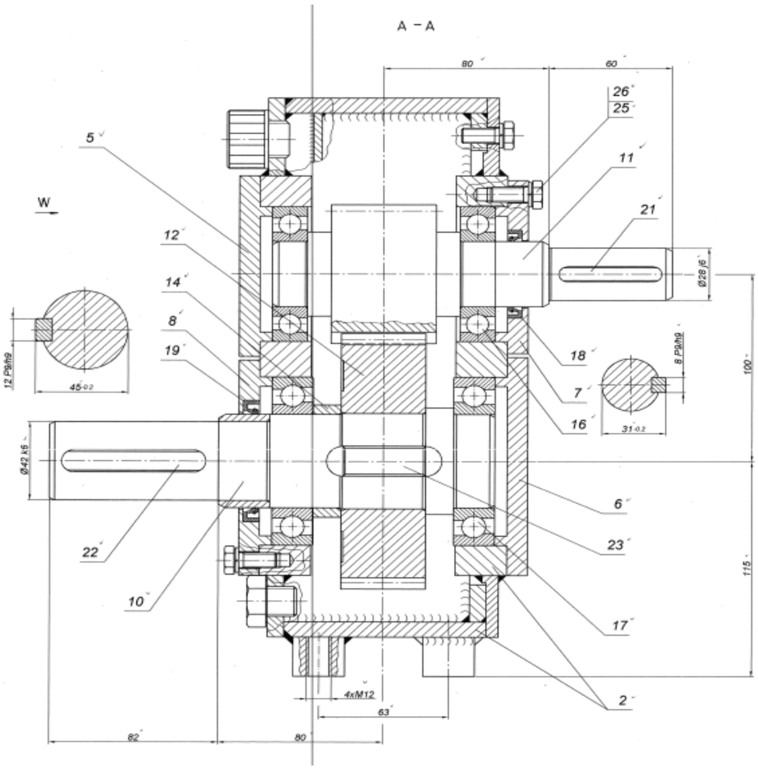

Fig. 2. Diagram of analysed gearbox: 2 – body; 5, 6, 7, 8 – bearing caps; 10 – roller; 11 – pinion; 12 – toothed wheel; 14 – spacers; 16, 17 – bearings; 18, 19 – seals; 21, 22, 23 – inlets; 25, 26 – washers, screws

$L_{kA}=24$
$L_{kB}=81$
$L_{kA}+L_{kB}=105$
$W_{ep} = 24/105 = 23\%$

On the basis of such defined values of the index and coefficients, it is possible to proceed to shaping the design of the product from the point of view of technological assembly. Due to market demand, production costs and delivery times to the customer, general purpose gearboxes are designed in the form of series. The series consists of several gears with the same design but different geometric dimensions.

4. SUMMARY

It can be stated that analysing the parameters values of technological evaluation of the gearbox assembly:

- evaluation of parameter values (table 1) may be basis for the analysis of the product design,
- assessment should take into account many other factors related to sales, service, availability of spare parts, production volumes, types of equipment, available assembly techniques, level of automation, cooperation services, commercial components, technical culture, etc.

Lucas DFA analysis is one of several methods for the technology of a product's design evaluation – it allows assessment of assembly technology in terms of time criterion and thus assembly costs. The method can be successfully applied also to smaller batches of manufactured products for the manufacture of a group of technologically similar products – e.g. general-purpose gears. The use of standardization of assembly operations is helpful in assessing construction – it makes it easier to determine the time of these operations.

The ability to evaluate the design is conducive to the creativity of the designers – procedure discussed in the paper can be carried out for the product and its components (assemblies, components, etc.).

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Knowledge base system, Decision-making process

Richard WOROBEL* Peter BUBENÍK**

DESIGN OF A KNOWLEDGE BASE SYSTEM FOR DECISION SUPPORT AT THE SALES DEPARTMENT IN THE PRINTING INDUSTRY

Abstract

The article describes the design of a decision support system that aims to increase business profitability through knowledge. The design of the system is aimed at the business department in the printing company. The paper presents the current decision-making situation in the company, followed by the presentation of the system design.

1. THE CURRENT SITUATION OF DECISION-MAKING PROCESSES IN THE COMPANY

Today's modern times are symbolized by a high degree of computerization in every single area of our lives. For businesses, this means a large amount of data that needs to be processed for the necessary information and knowledge. In terms of competition, it is important for the company that its employees have this knowledge to acquire, and then used this knowledge at the right time and advantageously for the enterprise.

In most enterprises, a production system model is used, as shown in FIG. 1. [1]. The production system model is divided into the following phases:

1. The customer is in contact with the **sales department** or sales representative of the company, which leads to the acceptance of the order.
2. The merchant accepted request is then processed to order. At the **planning** and **purchasing departments,** a proposal will be made: How the product will be manufactured and from which material.
3. **Manufacturing** takes place according to the instructions of the **technology department**, the product is manufactured on scheduled machines, with planned people, in the required quantity, and at the required date.
4. The goods are transported and packaged according to the customer's requirements in the **shipping department.**

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5. The customer shall receive the required goods in the required quantity, quality and agreed price to be paid at the agreed date.
6. The **finance department** divides the amount of money received into the enterprise and determines the benefit of the contract based on the calculations.

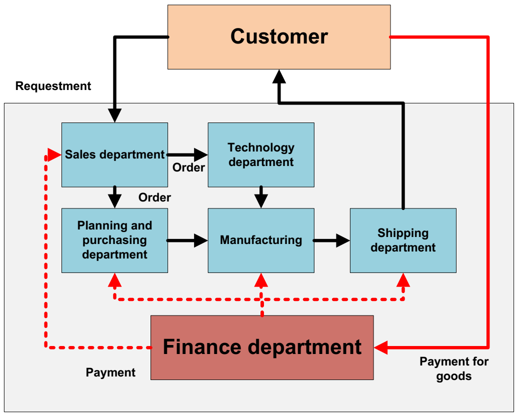

Fig.1 Production system model

This production system is the same in most companies, sometimes there are smaller differences between companies, depending on the type of production. The type of production also determines the degree of employee knowledge needed in decision-making processes [2].
The most important department in decision-making is the business department. Employees in this department determine the production composition. That is why I decided to analyze the decision-making processes in sales department in the printing company (FIG.2.).

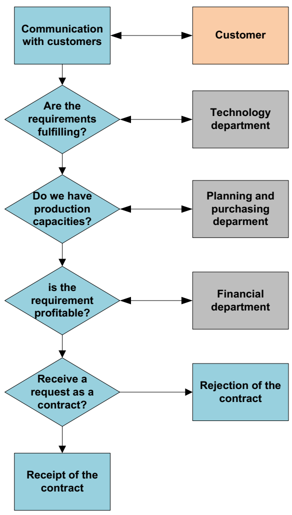

Fig.2 Decision-making processes in sales department

The following shortcomings were observed in decision-making processes:

- The Business Department has accepted contracts that cannot be produced technologically.
- The Business Department has made a bad offer for a customer - financially disadvantageous for the business.
- Receiving multiple orders with similar production methods - manufacturing cannot effectively produce the same amount of product in a row.
- Accept a large number of orders with a small percentage of profit.

These deficiencies are due to insufficient knowledge sharing across departments, resulting in bad decisions by sales representatives. These identified shortcomings affect the entire business. List of some of the negative impacts on the business:

- Offer rejection from customer due to incorrect price.
- Customer rejection offer due to long decision time (bid creation).
- Ineffective production.
- Not reaching profit even in the strongest months.
- Sales representative is repeating bad decisions when receiving customer orders.

Businesses mostly use information sharing systems such as the manufacturing information system or various decision support programs but a comprehensive decision-support system at the sales department that accepts customer orders to support the company's planned profitability are missing [3].

2. DESIGN OF A KNOWLEDGE BASE SYSTEM

The proposed knowledge base system will comprehensively recommend a production mix for the sales department within a specified timeframe. By sharing information from the sales, technology and production department, and their transformation into knowledge, effective production should be achieved. The design of the system is composed:

- **Define Manufacturing Representatives:** Representatives differ amongst themselves by selected parameters that are broken down by impact on the technological process and hence on the total cost of production. The designated Manufacturing Representative should have a specific name that can clearly define which representative is involved. Consequently, it is necessary to create and define categories that specify the quantity of production, and the last point is to determine by coefficient the influence of the representative itself on the profit of the enterprise.
- **Data and Information Collection and Arrangement:** Analyze data and information in a manufacturing enterprise related to the production of individual manufacturing representatives. It is necessary to ensure that the data and information in the system are constantly collected and updated so that the proposed result reflects the real needs of the company.
- **Transformation information into knowledge:** Creating a knowledge matrix and identifying the impact of production representatives on profitability. The following steps must be taken in transformation:
- Verifying the information and data accuracy.
- Transformation data and information, into knowledge, using KNIME Analytics software.

- Create a mechanism to regularly update the necessary knowledge (to incorporate market and planning impact)
- **Creating a rule:** Use a knowledge system to find a rule that determines the right combination of products, recommend a more advantageous combination of a business mix.

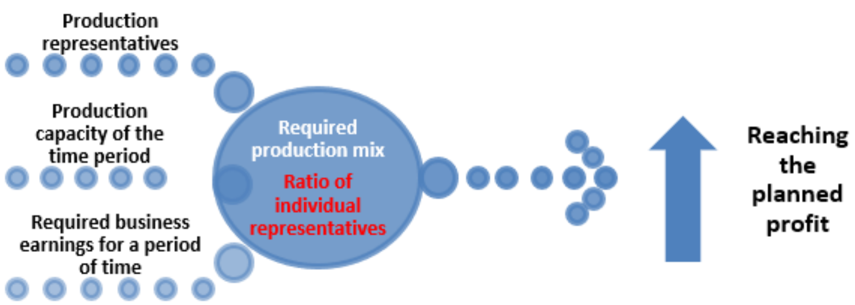

Fig.3 Example of rule making

- **Create a control system:** Once a rule is introduced, a control mechanism is created using an information system that will not only help merchants to make and receive orders but will prevent acceptance of contracts that do not comply with this rule.

3. CONCLUSION

Many times, the production department is responsible for the poor performance of the planned profit. However, in most companies, they follow the decisions of the sales department. By proposing the solution, the proposed system is designed to achieve sharing of information and knowledge, using the knowledge system of the sales department, which would recommend the merchant a suitable product mix that ensures the profitability of the firm.

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Machine Vision, Object Recognition, Reconfigurable Manufacturing Systems

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OBJECT RECOGNITION IN THE ENVIRONMENT OF RECONFIGURABLE MANUFACTURING SYSTEM

Abstract

Machine vision is a rapidly growing industry focused on analyzing, modifying and understanding the image. Its task is to decide in real time what is going on in front of the camera lens and use this information to manage a computer or robotic system.

1. INTRODUCTION

The dynamically changing production environment of reconfigurable manufacturing systems, which often changes the layout of devices in the workspace, and also allows the presence of a man-operator in environment requires active scanning of surroundings of mobile robotic system to achieve smooth and safe motion. One possibility is machine vision, when the surroundings the mobile robotic system is monitored and evaluated in real-time.

2. OBJECT TYPES IN MANUFACTURING ENVIRONMENT

There may be various obstacles in the working space of the mobile robotic system, which can obstruct its free passage through the proposed route.

2.1. Part of the system

The obstacle that is part of the system is an obstacle, which location is known for a multi-agent control system. This may be a modular platform, or another mobile robotic system. This kind of obstacle does not affect the functionality of the mobile robotic system.

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2.2. Static obstacle

The term static obstacle means an object that is not mobile and its presence in the environment can affect performance of the mobile robotic system function.

2.3. Dynamic obstacle

A dynamic obstacle is an object in the workspace of a mobile robotic system that dynamically changes its position. Such an obstacle may be a person or a vehicle that is not part of the system.

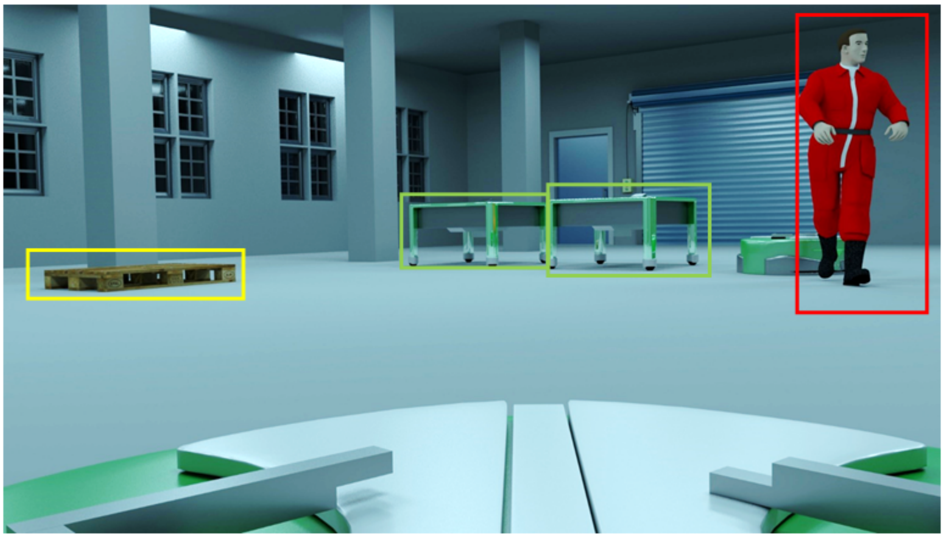

Fig. 4: Detected objects in environment - part of the system (green), static obstacle (yellow) and dynamic obstacle (red)

3. OBJECT RECOGNITION AND SYSTEM REACTION TO OBJECTS IN ENVIRONMENT

During motion of the mobile robotic system, camera is scanning surroundings of mobile robotic system. Images from camera are then processed, edited and evaluated and then the information about these objects is transferred to multi-agent control system.

3.1. Object recognition

Since the mobile robotic system is moving, it is necessary to process the scanned image and adjust the motion to evaluate the result. The first step is image pre-processing, when the scanned image is adjusted to make it easier to find various objects in the environment. This is achieved by changing the RGB image to a colour scheme more suitable for image recognition, and the system then looks for sharp edges in the image. The next step is to estimate actuall position when position of mobile robotic system changes over time. The next step is to quench the motion estimate, and the last step is to adjust the image size. In this modified image is possible to recognize pre-learned objects and then discern whether it is a static, dynamic obstacle, or partition of the system.

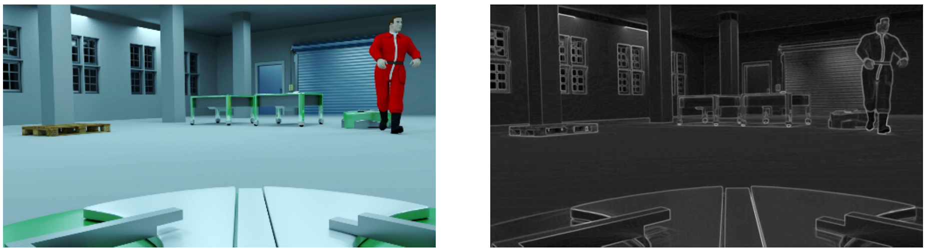

Fig. 5: Image processing from RGB picture to grayscale picture with detected sharp edges

3.2. System reaction to objects in environment

After recognizing the objects in the environment, it is decided what kind of obstacle is involved. If a part of the system is recognized, mobile robotic system does not change the route and it continues its motion. In the case of a static or dynamic obstacle, the information about the type, dimension, and location is sent to the multi-agent control system. Multi-agent control system then decides whether the mobile robotic system should stop and wait for a dynamic obstacle to move from the mobile robotic system path, or if it is a static obstacle, the system will determine the new route of the mobile robotic system, whereby the mobile system moves to its target position.

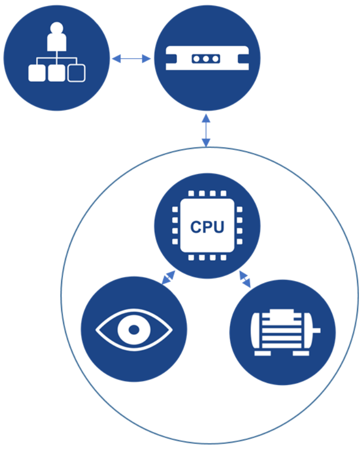

Fig. 6: Communication between Multi-agent control system and mobile robotic system

4. CONCLUSION

Older technologies for navigation of mobile robotic systems are currently being gradually upgraded by camera vision. These guidance technologies provide greater system flexibility and simplify route modification when changing the layout of the production or warehouse environment. These solutions also allow the vehicle to respond to potential obstructions along the route by avoiding them and to accelerate the transfer of material by finding the shortest route to the target position. Camera guidance itself may in some cases be less accurate. For this reason, in the proposed solution the camera is used only for obstacle detection and for the navigation of the mobile robotic system it is proposed to use another alternative of navigation and also the guidance system is connected with positioning by means of encoders and accelerometers, thus achieving suitable accuracy of the vehicle for use in industrial environment. Unlike laser guidance, the camera can tell exactly what kind of obstacle it is and then evaluate the most appropriate response of the mobile robotic system. However, since image processing is more demanding in the near real-time for computing performance, it is necessary to customize the mobile robotics control unit.

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