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CONTENTS

CONTENTS

CONTENTS

CONTENTS

Industrial ergonomics, Ergonomist, Health and safety

Monika BANACH*, Kinga BYRSKA-BIENIAS**

ERGONOMIST IN THE ORGANIZATIONAL STRUCTURE OF THE ENTERPRISE

Abstract

This article is a collection of information about the role, powers, competences and requirements of people working on ergonomics in manufacturing companies. Interdisciplinarity in this area makes determining the right place in the organizational structure, especially in large enterprises, one of the most important success factors.

1. INTRODUCTION

Large international companies are currently experiencing enormous pressure on issues related to ergonomics. Meeting the requirements of safe and hygienic working conditions is no longer sufficient. This is evidenced by client audits, which point to each of these positions that are not properly tailored to the operators.

In small businesses, the ergonomist is usually the owner of the enterprise, making his decisions in an intuitive way and does not have the education or experience to do so. This makes ergonomic solutions seem to be ergonomically justified and is part of the marketing of the products sold to companies that do not increase their comfort at work. On the other hand, the costs of bad decisions in this case are the smallest and concern a very small number of employees. [2, 4]

In medium-sized companies, the issue of job adaptation to the physical capabilities of a human being is usually dealt with by health and safety specialist, and this is one of the additional responsibilities in addition to the numerous responsibilities. Often the issues of ergonomics are often overlooked and ergonomics is a side effect of the implementation of legally required solutions.

In large enterprises, 600 full-time employees have 1 full-time health and safety post. Also in such enterprises, the responsibility for the implementation of ergonomic tools lies with the inspector of the service. The reason is that it is difficult to clearly define the responsibilities, scope, requirements and competences for industrial ergonomics. His skills must be

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interdisciplinary. The highest efficiency is achieved in team work rather than single stand alone. [2]
The second most commonly used solution is the creation of fixed or variable assemblies involving people involved in the Health and Safety, Logistics, Lean - slimming production, machine building and maintenance. Thanks to this, the proposed solutions cover many aspects of operation - standard and emergency mode of machine operation. But still, the responsibility for the implemented solutions is fuzzy - if the team is responsible it really is not responsible for any person directly. The best solution is to identify the leader of such a team / unit and monitor the effects of the work. The expected outcome is continuous team learning and continuous improvement of the organization management system. [3, 4]
In response to the above-mentioned problems of the human resources department, who wanted to actually specify the position of industrial ergonomics, the presented article was prepared.

2. DEFINITION OF POSITION NAME

Ergonomics, as defined by the International Ergonomic Association (IEA), is a scientific discipline the explores interactions between people and the rest of the system.
The ergonomist uses his theoretical principles, data and methods to design effective work systems that take into account human well-being. [1]
It is possible to propose the names of different positions – company ergonomist, industrial ergonomist, rationalization of work ergonomics, ergo-inspector, engineer ergonomics. The use of names without a word ergonomics due to the interdisciplinary nature is unfavorable, it obscures the fact the main purpose of the scope of work of such employee. In the case of a name such as eg. specialist of production improvement, no longer sure whether the ergonomic and improving material flow in the company or whether the purpose of the work will not only reduce the number of defects. [3]

3. SCOPE OF RESPONSIBILITIES

The activities of ergonomics are directed primarily at improving the technique and environment of human activity, on the other hand, on education, shaping, improving people and building in organizational culture employees. Tasks targeted at improvement are those that will ensure high performance (quality and performance). The next group of tasks is that which reduces the perceived hardship of work and every human activity at work, the essence is the creation of physical, mental, social and aesthetic comfort for the professionally active man. [1]
In the task of improving the human being itself, the technical and organizational executives, in turn, can distinguish responsibility for the ergonomics and knowledge of both the technology and its creators, the right choice for the profession and the work in the enterprise, facilitating adaptation to changing engineering, technology, lifelong and multi-faceted training of employees, organizing favorable conditions and social climate, proper organization of work and directing and supervising it in agreement with the health and safety service. [1]
Fig. 1. shows formation of ergonomic working conditions. Fig. 2. shows areas of ergonomics.

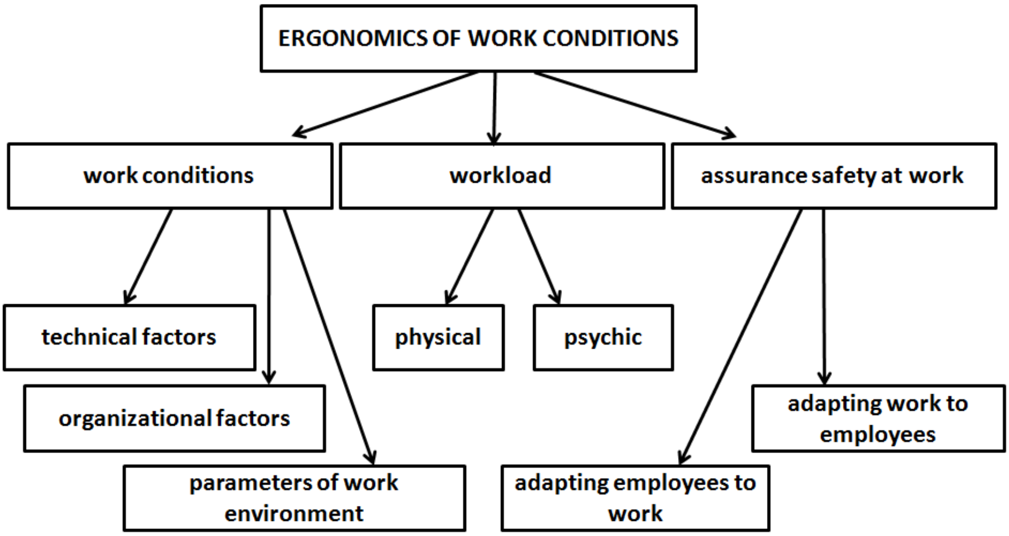

Fig. 1. Formation of ergonomic working conditions (own elaboration)

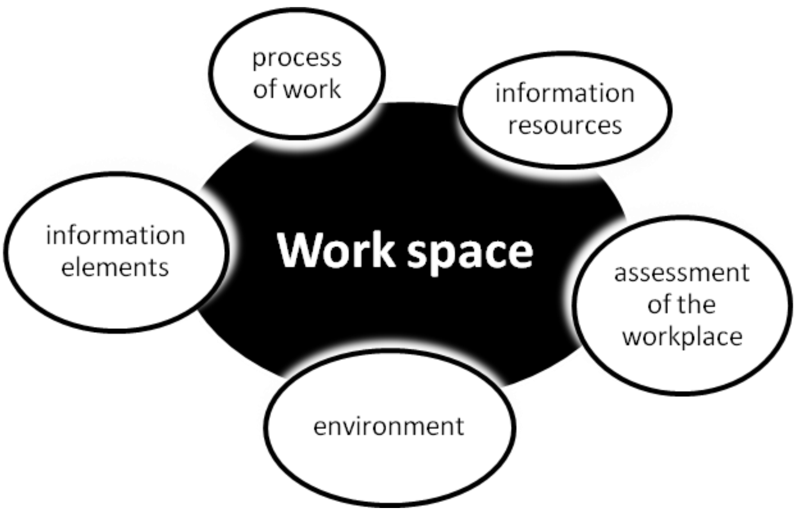

Fig. 2. Areas of ergonomics (own elaboration)

4. SUMMARY

Ergonomists use many different tools to their work such as ergonomic assessment sheets or other own tools. The names of these tools come from their inventors or company names where were developed. Although, this position is new and it is freshly created in modern enterprises, but the role of this position is significant.

Just as ergonomics, the ergonomist has to have interdisciplinary knowledge and huge experience at the same time knowing law and production processes. Copying ideas from another companies never brings such a good results as we expect. It has to be the base to create own elaborations and solutions complying with the company standards and the law.
One of main advantages of ergonomist is having high interpersonal skills. When recruiting an ergonomist, it is necessary to use the appropriate tools to verify the skills and personality of such person. One of knowing tool is Success Insights. This method allows one to assess a person on different levels (knowledge, personality, skills, etc.).
Market is demanding for competing organizations in present days. The heads of companies have to manage their workplaces on high level and with use of different methods and tools. One of good point for modern companies is to have ergonomist. The company has many profits because of this position. The ergonomist assess present workplace status (if it is ergnomic or not) and additionally the one cooperate with machines suppliers to help them create the best in terms of ergonomics workplace.

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Internal logistics, Simulation, Order picking processes, Warehousing

Monika BUČKOVÁ[*], Martin KRAJČOVIČ[**], Dariusz PLINTA[***]

OPTIMIZATION OF LOGISTICS OF ORDER PICKING PROCESSES WITH USING COMPUTER SIMULATION

Abstract

This article deals with optimizing of internal logistics during orders picking processes by human. In article are described basic steps of logistics of order picking process in order to minimize distances traveled by human. The basis of this solution is execution of computer simulation and simulation experiments for faster finding of correct solution, which causes reducing of pickup time of order picking processes.

1. WAREHOUSING

Flexible fulfillment of unstable customer requirements and ongoing pressure to reducing costs from realization of many individual customer requirements can not be achieved without major changes in the management of the entire warehouse system, internal logistics and at the end in integrated logistics chain. Nowadays, everything is variable, the products are different and warehouse operations are often changing. Fulfillment of customer requirements entails the need for continuous development of technology, software and integration between them. Warehouse has a significant impact on ensuring a higher level of customer service and the protection of using properties of the goods. This is the reason why optimization of logistics of order picking processes is one of the most important areas in warehouses.

2. USING THE COMPUTER SIMULATION FOR OPTIMIZATION OF ORDER PICKING PROCESSES

Picking of goods could be relatively complicated operation, it can be carried out by individual orders or across doses. One picked dose may contain any number of individual orders, which for some reason could be processed as a single dose. For example, when a request for ordering a few orders comes to the warehouse, for example, for a particular carrier or for a particular delivery line. For these reasons, it is advantageous to use computer simulation as a tool for

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optimizing the picking of goods. Since the simulation works with the simulation model created on computer, it would be time and costly difficult to capture all the processes that are running in warehouse. Therefore, before the formation of the model itself it is only necessary to determine the relevant processes and relationships that affect on system in view of the goal that must be achieved by simulation experiments. Therefore experimentation phase is usually the most interesting phase of the project, because it begins to bring first results. An inseparable part of each simulation project are statistical analysis, which can create a discussion about results of experiments, it brings new ideas and possibilities to improve simulation models [4]. Software suitable for computer simulation, for example Tecnomatix® Plant Simulation 13, show not only statistical results but also models in 2D, 3D mode or 2D / 3D mode. Latest releases of this software allow presenting concept of system in a complete virtual, more interactive environment [1]. Objects and their individual elements created in 3D models can also be animated in a computer simulation.

(a)

(b)

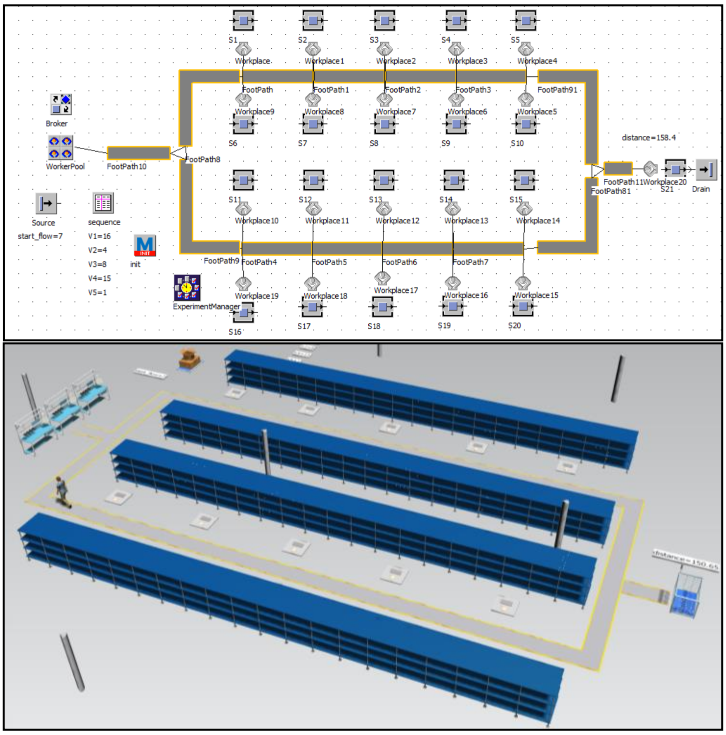

Fig. 1. Example of 2D model (a) and 3D model of warehouse (b)

In Fig. 1. it is possible to see a example of model of warehouse that was created for optimization needs of logistics of picking goods by worker. There are countless number of options how to optimize the logistics of picking goods. Picking of goods can be carried out by warehouse dynamic device, by handling equipment or by a worker who is searching for goods. For this example (Fig. 1.) is selected fewer orders due to the large number of possibilities of diversification so we can use the foundations of permutations without repetition, e.g. M is a set of n different elements, which form the n - tuple, with elements of n - tuple can´t be repeated.

$$P(n)=n! \qquad (1)$$

n! - Factorial

Manual calculations of the permutation type could be used for calculation of lower order numbers and storage locations in the warehouse. With five orders V1, V2, V3, V4, V5, and five of storage locations S16, S4, S8, S15, S1, we can consider the 120 possibilities of loading goods, so that worker can find order as quickly as possible, in the shortest possible route. For quick evaluation of such a large number of experiments it is possible to use software tools, as a Experiment Manager in Tecnomatix Plant Simulation 13. Through simulation, it is possible to capture and evaluate all events that occur and are recorded during the dynamic viewing of process, which simplifies work and evaluating of results. The more variations created by software of this dynamic system, the higher is probability that the choice for us could be most preferred [2].

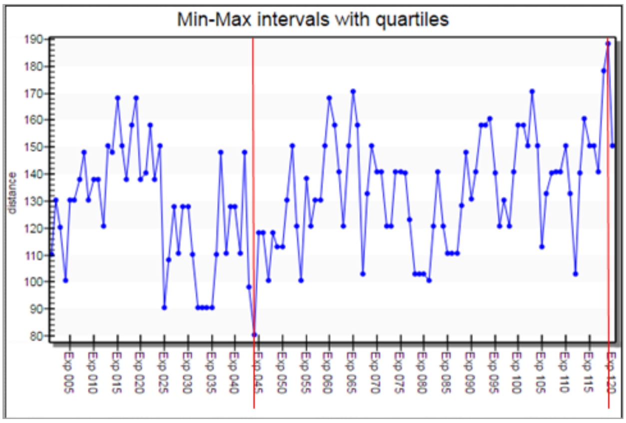

Fig. 2. Graph of “Experiment – Distance” created in Tecnomatix Plant Simulation 13

In this graph, Fig. 2. experiments are displayed on the x-axis, and the traveled distance by the worker to pass orders V1, V2, V3, V4, V5 on the y-axis. The graph shown in Fig. 2. is automatically generated by Tecnomatix Plant Simulation 13 software, while the red lines shown in the graph were drawn later, to marked experiments Exp044 and Exp119. Based on this evaluation, it is possible to say that the worker passed the shortest distance in experiment Exp044 when combination of orders was V1 - S16, V2 - S1, V3 - S8, V4 - S4, V5 - S15 and the longest for experiment Exp119 when combination of orders was V1 - S4, V2 -S16, V3-S8, V4-S15, V5-S1. In this way, it is possible to evaluate the distances that would not be experienced only by the worker but also by the various handling equipment or their combination. This example was created for a low number of orders. The higher number of orders is, the harder it is to create experiments. For the user it is difficult to recalculate permutations without repetition and immediately determine the route for worker or for handling equipment. Therefore, to solve these optimization problems could be used for example genetic algorithms [3].

3. CONCLUSION

Using the Tecnomatix Plant Simulation 13 software, which is used on Department of Industrial Engineering, it is possible to create an interactive 3D warehouse model, optimize logistics systems, transport routes, picking of orders processes and get very specific results [6]. In this practical example of optimization of internal logistics of picking of goods in computer simulation, it is possible to see how long the process of calculating the paths of workers can be. The results of computer simulations show how long distances the worker had to go to set order. The higher number of orders is, the more time-consuming it is for user to determine the shortest and longest transport route for picking of orders. By improving ergonomics of work, shortening of transport routes, productivity of workers could increase, and on the other hand for example exhausting or tiredness of workers, risk of occupational accidents or occupational diseases decreases [5].

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Production engineering, Ergonomic assessment sheet, Ergonomics of manual work

Kinga BYRSKA-BIENIAS*, Monika BANACH**, Dominik PITLOK***

METHODS OF ERGONOMIC ANALYSIS IN MANUAL ASSEMBLY WORK

Abstract

The article provides how we can support the risk assessment and ergonomics diagnosis by using two tools: KIM-MHO method (en. The Key Indicator Method for Manual Handling Operations) and NIOSH method (en. The National Occupational Safety and Health Lifting Equation). The article points to necessity monitoring analysis result, but also legal requirements for the weight of moving objects in a given country.

1. INTRODUCTION

Enterprises constantly developing their health and safety management systems. Organizations with a higher level of ergonomic culture choose to use ergonomics sheets developed by other institutions or companies or organizations develop their own diagnostic tools.
Ergonomics, as defined by the International Ergonomic Association (IEA), is a scientific discipline the explores interactions between people and the rest of the system.
The ergonomist uses his theoretical principles, data and methods to design effective work systems that take into account human well-being. [2]
The specific tools of ergonomist work are previously mentioned the diagnosis sheets. They are described in the literature. There are many research methods dedicated to specific work groups and selected workloads. There are described methods in *Handbook of Human Factors and Ergonomics Methods*, where authors divided ergonomics tools into groups. These groups are shown in table number 1. [4]
Due to the requirements of the Labor Code, art.226, employers are required to carry out the risk assessment analysis. These analyzes cannot be limited to basic information. Currently, detailed guidelines are required from employers, for example in the area of chemical risk. There is also necessity to pay a lot of attention to the way employees perform their manual work. [8]

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Musculoskeletal disorders of the upper limbs are still common in working population. Besides of work with computer, the high mass loads, high forces, ergonomic postures and repetitive movements are the most commonly mentioned physical factors associated with work. [3, 6, 1, 5]

Tab. 1. Examples of ergonomic diagnostic tools [4]

Group of method	Method – Full name / explanation of method
Physical methods	PLIBEL - A Method for Identification of Ergonomic Hazards
	NIOSH - American National Institute for Occupational Safety and Health – indicator of the recommended limit value RWL
	REBA - Rapid Entire Body Assessment – quick overall assessment of body position
	Muscle Fatigue Assessment-Functional Job Analysis Technique
	The Occupational Repetitive Action (OCRA) Methods OCRA Index, OCRA Checklist
	OWAS - Ovako Working Posture Analysis System
	The Strain Index
Psychophysical methods	EMG - elektromyography
	EEG - outpatient electroencephalography
	ABPM - Ambulatory Assessment of Blod Pressure to Evaluate Workload
	EDA - Electrodermal Activity Measurement
Behavioral and cognitive methods	HTA - Hierarchical Task Analysis
	CDM - Critical Decision Method
	Mental Workload
	SAGAT-Situation Awareness Measurement and the Situation Awareness Global Assessment Technique
Environmental methods	Thermal Condition Measurement
	Heat Stress Indices
	Noise Reaction Indices

Each method of ergonomic analysis is recommended for specific workplace conditions. There are two useful methods: KIM-MHO (The Key Indicator Method for Manual Handling Operations) and NIOSH method. NIOSH method was modified many times and we can meet simplified variants, for example LHAW method (Hazard Assessment Worksheet). The card has been developed according to experimental-theoretical assumptions Revised NIOSH Lifting Equation

The results obtained with the use of ergonomic sheets should also be compiled with the country's legal requirements.

2. ASSUMPTION OF KIM-MHO METHOD

In order to determine the validity of a risk assessment criterion, the study of employees in different workplaces is done through standard questionnaires and interviews of symptoms of

stress experienced in the neck and upper limbs. Body postures are also analyzed in the course of performing specific activities.
The KIM-MHO method has been developing since 2007. There are also very similar methods for other types of work: Lifting/Holding/Carrying (KIM-LHC) – tools for lifting and holding work and Pulling/Pushing (KIM-PP) – tools for pushing and pulling work.

3. ASSUMPTION OF NIOSH METHOD

The NIOSH method is used to calculate the recommended weight values for weightlifting. By using a properly constructed equation, the recommended RWL limit value is calculated. [7]

$$RWL = LC * HM * VM * DM * AM * FM * CM \quad (1)$$

The individual coefficients mean the sizes listed in Tab. 2. [7]

Tab. 2. Formulas of coefficients in NIOSH formula [7]

Name of parameter	**Symbol**	**Equation / value**
Load Constant	LC	23 kg
Horizontal Multiplier	HM	25/H
Vertical Multiplier	VM	1-(0,003*(V-75))
Distance Multiplier	DM	0,82 + (4,5/D)
Asymmetric Multiplier	AM	1-(0,032*A)
Frequency Multiplier	FM	Read from the value table given in the method
Coupling Multiplier	CM	Read from the value table given in the method

The individual symbols means [7]:
H - hand distance between center point between ankle joints; Measurement in initial position and target lift [cm]
V - vertical distance of hands from the floor; Measurement in initial and target weight lifting [cm]
D - vertical distance of displacement [cm]
A - asymmetry angle, angular displacement of weight relative to sagittal plane.

The process of shaping the working conditions associated with the manual transport of weights is done by identifying activities that are particularly burdensome to the motion system, and then selecting a variable task, or selecting a maximum mass not exceeding RWL. Based on the RWL value and the weight of the lifting object L, it is possible to determine a lifting index LI that speaks of the magnitude of the postural stress associated with this task.
This indicator is defined as follows [7]:

$$LI = (\text{lifted weight}) / (\text{recommended limit weight}) = L / RW \quad (2)$$

where: L – weight of the lifted object in kg.

The method helps to assess lifting conditions by setting a weight limit for manual lifting. It was developed based on the research of a selected group of workers, does not take into account gender or age. The NIOSH method used in the form of the NIOSH equation should not be used when: lifting is done by one hand, lifting in a sitting or kneeling position, lifting takes place in limited space, the item being lifted is unstable, lifting is carried out when moving, pushing or pulling, lifting by means of a wheel or shovel, high speed lifting (> approx. 75cm / s), work is done in an unfamiliar environment, distance greater than two steps. [7]

4. SUMMARY

The paper presents two methods of evaluating ergonomics. Both methods were used to evaluate the same workplace. The KIM-MHO method takes into consideration considerably more aspects than the NIOSH analysis. By applying the first method to the middle level, the organization responsible for work organization should consider reorganizing the work, while the NIOSH method focuses on the aspect of displacement, so the resulting result is a very low ergonomic risk. The methods should therefore be used in parallel so that the ergonomic assessment takes into account a number of evaluation criteria.

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Expert system, Knowledge system, Knowledge engineering

Juraj ČAPEK[*], Peter BUBENÍK[**]

KNOWLEDGE SYSTEM OF A MANAGER

Abstract

The article introduces a knowledgeable and expert system with its components and instruments for creation. The high degree of computerization in all areas of our lives brings also an enormous amount of data, which very often contains information and knowledge resulting from real processes and relations. Knowledge and its subsequent application mean a highly valuable source in the work of a manager.

1. INTRODUCTION

With the rapid development of information technologies, the Internet in particular, the speed of information data transfer decreases, and the distances and the volume of information availability increases significantly. The number of mobile applications supporting not only the world of entertainment but also solutions for services and the manufacturing industry increases exponentially.

In the world of a manager, information as such is often understood as:

- means of creating plans, orders;
- raw material for supervision and operational management;
- source of knowledge about the society and its surroundings
- instrument for organization and coordination of the activities of the managed team
- subject of communication in the system, a necessary condition for recognizing the current state of the controlled system

The information can be viewed as a dimension characterized by:

- **time**, which means the information is very time sensitive. The good decisions require information to be given when needed. The up-to-date information expresses the relationship with the present.
- **content**, information is usually considered the most important dimension. Preciseness is a vital attribute in life. Information has to be relevant – it has to correspond to the needs for which information is required. For the comprehensiveness to be ensured, all relevant information must be provided.

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- **form**, information emphasises the fact that it must be attractive, easily comprehensible, and usable. The dimension of the form means providing such information that has its clarity, detail, sequence order, presentation, and media..

2. KNOWLEDGE AND WISDOM

Knowledge is often characterized as information which is transformed into a level of practical application and use. If there is such information, thanks to which it is possible to make the right decision, available, it becomes knowledge. It gives an answer to the question 'How?' Knowledge can be represented by information and above that by 'something extra', which helps the information receiver execute the right decision. It applies that if two people dispose of the same information, it does not have to mean the same knowledge to both of them (to some, it does not mean knowledge at all).

Basic knowledge typology:

- **Explicit knowledge** is knowledge which can be expressed in a formalized way. It is possible to formulate them easily with letters, words, and/or characters. After explicit formulation, we can in fact say that this is information.
- **Tacit knowledge** is knowledge which cannot be formalized. It is a set of experience, abilities, intuition, and personal perceptions. It is highly personal and often hidden in people's sub-consciousness..

The transfer of the knowledge from the one form to another is enabled by so-called conversion of knowledge. Example:

- **Tacit to explicit** (externalization – articulation). It is a process of verbal formulation and codification of tacit knowledge.
- **Explicit to tacit** (internationalization – acquiring). This process is linked to the use of explicit knowledge (getting it into one's own knowledge structures). This requires working with explicit knowledge or information, its understanding and consequential internalization.
- **Explicit to explicit** (combination – combining). Explicit knowledge can be shared and transferred with the use of documents and emails. Such an example can be saving a message to where it is accessible to all the employees of the company. In such a process, information technologies are very useful.
- **Tacit to tacit** (socialization – experience). When an apprentice learns from their master, we talk about socialization (from tacit knowledge is tacit knowledge created again).

Wisdom is the ability to use knowledge effectively, to our benefit and growth. It is at the very top of the pyramid. By using (training, testing,…) knowledge, we gradually gain experience, which increases the level of our wisdom in the field.

3. KNOWLEDGE AND EXPERT SYSTEM

The Knowledge System (KS) makes such knowledge (findings) which can be used at different levels of management available. The need for creation of a knowledge system stems from the fact that specialists from different areas, so-called experts, who have knowledge from a specialized area are very valuable, their services are expensive, and they are usually very busy. However, knowledge is usually required from a number of areas, and there is a risk that if the expert changes their occupation or place of work, the necessary knowledge is lost or lacked.

For the reasons described above, it would be very useful if experts from certain areas were 'computer-implemented' and thus made available within an organization; for example, to all employees they can help when solving problems.
The concept of The Expert System (ES) was created and used for the first time at the turn of the 70s and the 80s of the twentieth century. The most frequently cited definitions of the ES concept come from Edward Feigenbaum (the creator of the first ES in the world).
'The Expert System is a computer program simulating the decision-making activity of an expert when solving more complex tasks, and using appropriately coded, and explicitly formulated knowledge adopted from the expert, with the aim to achieve the quality of decision-making at the expert level in the problem area chosen' [1].
As each application area requires different representation of knowledge as well as a different control mechanism, most of today's ESs have the character of special problem-oriented systems.
The terms knowledge system and expert system are sometimes incorrectly considered synonyms. **The Expert System** is such a knowledge system in which the expert's knowledge is used in precisely determined problem area, and thus it is a special type of KS, which is characterized by the use of expert knowledge and some other features; such as an explanatory mechanism.
Nowadays, both the knowledge systems and the expert systems are used in diverse areas of human activity. Since the variety of applications is very large, the area of human knowledge is very wide. The most common application areas are medicine (disease diagnosis), prognosis, trade, finance (loans and bank credits administration), insurance (insurance risk classification), industrial diagnostics (equipment failure identification), army etc.
The main benefits of knowledge systems include:

- the possibility of wide access to knowledge,
- cheaper services such as the service of the experts,
- unlimited knowledge storage,
- excluding mistakes committed by a person while applying knowledge,
- increasing the knowledge of the people who use them

4. BASIC PARTS OF THE EXPERT SYSTEM

The development of technologies, in the recent years, has allowed by the automated means of computing to search for knowledge from the data available. The core of the expert systems is the **Knowledge Base**, which includes the knowledge of the experts in a certain compressed form and in a particular problem area. There are more ways of representing knowledge. They are usually represented by **facts** and **rules**. The most prominent tools for creating a knowledge base and rules are the PRO-LOG, ADA, and LISP programming languages; and in the recent years, widely used in the US, the highly-developed CLIPS (C Language Integrated Production System), created in 1984 in the NASA Artificial Intelligence section [2].
The second component part of the expert system is **the inference mechanism**. It is a mechanism that examines facts, rules, and provides a response to the question addressed. Every variation of fact-compliant rules is understood as a partial answer. The inference mechanism is something like a thinking part that has the ability to browse the database and apply rules to solve a partial problem. The demands for "rule systems" take, again, the form of rules. In the example above, 'Appropriate pair' may be understood as a query if it is used in this sense, and as a rule if it occurs as a condition for completing another query. Other components of the ES are the **explanation mechanism** and the user interface. The ES is able to recommend a solution to the user and justify the proposed solution; with active user participation in the solution or evaluation. The issue of ES creation is dealt with by the Department of Artificial Intelligence - Knowledge Engineering. Knowledge engineering

engagement comprises of the creation of problem-independent expert systems as well as the acquisition of knowledge from experts, and automated data acquisition issues.

5. KNOWLEDGE ENGINEERING

Knowledge engineering is software engineering applied to the creation of knowledge systems. Those involved in the creation of knowledge systems come from a wide range of expertise (scientists, knowledge specialists, system analysts, psychologists, project managers, experts from different domains). Basic requirements regarding the capabilities of a knowledge engineer include the ability to acquire information from experts using different techniques; which requires them to understand the information the same way as the experts; furthermore, to know how to translate them into the form in which they will be represented on the computer. For the knowledge engineer, knowledge of these techniques and trends must be a matter of course.
Knowledge systems can be categorized as follows:

- **Expert systems** - they are closest to the definition of knowledge systems, and often these two concepts are mutually confused. Expert systems emulate decision-making processes and actions by an expert or group of experts.
- **Intelligent Database Systems** – these systems are database systems with a certain degree of intelligence added; they allow easier access to information than common database systems.
- **Intelligent teaching systems** – these systems model the teacher-person.
- **Intelligent CASE tools** – these tools enable to automate some software creation processes.
- **Integrated or hybrid systems** – these systems integrate access to knowledge systems and traditional information systems.

6. CONCLUSION

Nowadays, the question of efficiency gains in manufacturing companies is coming to a new level. In an effort to increase production and reduce costs, companies are beginning to process information and change them into knowledge. Managers are increasingly asking developers and suppliers for tools to support their management decisions. An important role here is played by the knowledge base, the preparation and creation of which requires a sensitive approach by the expert.
Solving these problems is often a long-term process in which an expert is needed. The second way of acquiring knowledge is through data mining, where it currently exposes a number of mining methods that bring success.

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Logistics, Healthcare, RFID, Nurse

Ivana ČECHOVÁ*, Ľuboslav DULINA**, Martin GAŠO***

THE USE OF RFID IN HEALTHCARE AND EFFECT ON WORK OF NURSE

Abstract

The logistic processes in Healthcare are same compared with the other areas. However, the need for traceability is higher. Logistics in Healthcare deals with the transportation of drugs, medical supplies, biological materials and the patients. Speed and minimization of errors have a high priority, so the logistic processes must be constantly improving. One way to speed up processes is to use RFID tags. This method has a positive impact on the mental health of workers.

1. LOGISTICS IN HEALTHCARE FACILITIES

Logistics is a very important part of the companies. It creates a connection between the physical flow of the product and the associated information. In Healthcare, logistics involves the movement of medicines, medical material, biological material, patient information, and patient transportation and manipulation. Well-managed logistics in Healthcare will ensure good health care, preceded by high-quality and efficient employee performance.

Logistics of drugs and medical supplies chain begins in production. The first part of the chain can be simply called industry. These include the purchase of raw materials, the production of final products, the management of stocks and the removal of it from storage. Another part is distribution and shipping. This part deals with the completion, removal and delivery of final products to the customers. The last part is Healthcare facility as the final station. He is in charge of the income and subsequent intra-company distribution of drugs and medical supplies.

Logistic of biological materials includes logistics of blood samples, microbiological examinations, urine and feces. Correct sampling, material storage and transport are a prerequisite for a quality sample for laboratory examination. The logistic string begins at a Healthcare facility where the biological material in vials are collected and closed. Subsequently, the transport from the medical facility to the laboratory is performed, where these samples are analyzed and evaluated.

The transfer and manipulation with the patients can be called intra-company logistics. These are activities that involve the transport of patients within a department or between individual

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departments of a medical facility. The patient is transported on a wheelchair or mobile bed. Part of this logistics is patient handling related to patient transportation. Patient handling, such as lifting, carrying, positioning, is a major problem for healthcare workers in terms of physical load. [1]
Logistics involves a constant flow of materials and information. In Healthcare, monitoring this flow is more of a priority because we can often talk about endangering health or life. Therefore, there is a higher need for traceability of individual objects in this chain. In addition to ensuring material at the right time, this also guarantees the availability of information that can speed up the process and thus save the patient's health. [2]

2. THE USE OF RFID IN HEALTHCARE

The new trend is to use RFID in the Healthcare sector as well. This technology greatly increases productivity, shortens times, and reduces costs. Among other things, there may be significantly shortened identification times, increased patient safety and overall quality of healthcare. Such evidence may lead to better traceability of pharmaceuticals, medical supplies or biological material samples. It is also possible to centralize information about the patients and their health status electronically, thereby speeding up the identification of the patients.
Traceability is the ability to track the path and current product location within the logistic chain. Traceability can be only when there is a link to information throughout the distribution chain. In the case of health care, it is a link between hospitals, pharmacies, distribution companies, and manufacturers. The key to the complete traceability of medicines and medical products is that they are already marketed by the manufacturer. Change of mark always compromises accuracy because errors may occur. [3]

2.1. Identification of drugs, medical and biological supplies

An important basis for identification is to be consistent throughout the distribution chain. If it is RFID tags used in the identification, it is possible. If the manufacturer adds an identifier in this chain, it is also possible to retrieve the identification in some part of the distribution chain using the terminal. This allows for easy traceability of the product and very good control of storage stock or effective removal of material from circulation. Using RFID, it is possible to mark and subsequently identify biological samples for laboratory analysis. Identification is useful because it avoids errors.

2.2. Patient identification

One of the often-mentioned concepts in healthcare is the patient's positive identification. This is a basic requirement for a well-functioning patient treatment process. Positive patient identification includes different types of verification and identification procedures to reduce error rates. Identification bracelets contain patient data (blood group, allergy, physician's name). If the data is stored in the RFID tag, it is available to the doctor or nurse before any examination. The main advantage of the use of bracelets is the rapid and flawless identification of patients. [4]
Real Time Location System (RTLS) is a system designed to track patient real-time position using active RFID tags. This technology serves to determine Patient Tracking within buildings or within the premises. RTLS typically consists of active tags, reference devices for tag

localization, data network, and application software for end users. In hospitals, RTLS can be used not only for tracking patients but also for asset tracking, staff tracking, and visitors. [5]

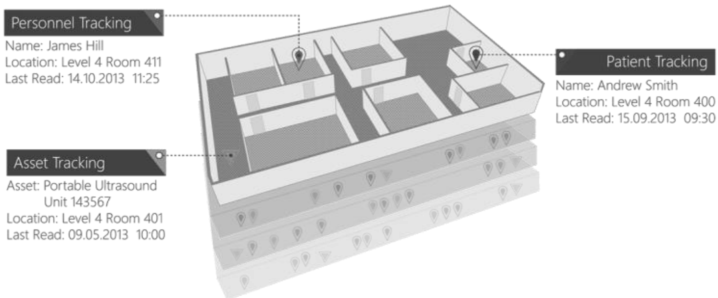

Fig. 1. Tracking patients, asset tracking and staff tracking [6]

3. EFFECT OF USING RFID TAGS ON NURSE WORK

Nurses responsible for all their work tasks are in daily contact with the patient under constant pressure. Pressure represents information, requirements, demands and expected results. Also in contact with relatives, they play an important role as mediator, often not good news. Stress is a daily part of their work. The fast pace of work, higher demands on work, steady decreasing the number of nurses, lack of aids leads to tension, disturbances or mistakes. The effects of stressors cause different physical, emotional, cognitive and behavioral disorders. Only by improving the organization of work, using available tools and teamwork, these negative factors can be eliminated. [7, 8]

3.1. The positive effect of using RFID

The studies confirmed that, among other things, the nursing staff is also stressing by administrative work increase to the detriment of patient care. One good example of burden mitigation is the identification of drugs, medical supplies, biological material and patients using RFID tags. This way, it is possible to support a paperless organization and eliminate administrative activities. Subsequent traceability of material and patients is also a way of facilitating nursing work thanks to technology. Traceability allows the nurse to quickly and easily identify the availability of drugs or medical supplies or the location of the patient. An important advantage of RFID is patient identification. Thanks to the bracelet with RFID tag, a nurse can positively identify a patient and read the data about him at any location in a health care facility without the need for paper documentation. An important advantage is also the increase in the nurse's speed as the search for records in the paper documentation is removed. It is replaced by documentation in electronic form which can be updated in real time according to the current state of the patient. The use of RFID in Healthcare saves time not only for nurses but also to doctors. It ensures that they can better and more heavily concentrate on fulfilling their professional duties, which is primarily patient care.

3.2. Barriers to RFID usage

One of the problems of using RFID in healthcare facilities may be the financial difficulty. The new technology implies some investment by the healthcare facility. Save Money, however, is possible if those chips circulate within the health facility and data are updated. One of the obstacles may be the lack of awareness of RFID systems and the increased use of barcodes. It is also important for this technology to be accepted by the medical staff and to learn how to work with it. It can also be a barrier because people do not always like to accept changes.

4. CONCLUSION

Usage RFID in Healthcare is also not a complete novelty, although we can talk about foreign countries for the time being. RFID like any other technology requires investment. This, however, ensures shorter times, increased patient safety and less congested medical staff. These benefits will never have other than a positive effect on the patient.

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Nurse, Physical load, Human postures, Patient handling, Handling aids

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PHYSICAL LOAD IN WORK OF NURSE AND AVAILABLE HANDLING AIDS TO ELIMINATE IT

Abstract

Nurses, as the most numerous group of healthcare workers, are affected by physical load each day. This load causes non-physiological working positions, in conjunction with patient handling, who weight well exceeds weight limits for load handling. Nurses are at risk of developing occupational diseases because of the physical load. The solution to eliminating this threat is to provide and use the available small and large handling aids.

1. INTRODUCTION TO THE ISSUES

Several types of health workers work in healthcare. The main purpose of their profession is to care for the health of the population. This work is demanding from a variety of perspectives. It requires certain personality assumptions, good physical and psychological health. The most vocal profession in healthcare is the nurse profession. Nurses represent almost 40 % of all healthcare workers. In absolute figures, for the year 2015, per the Zdravotnícka ročenka Slovenskej republiky 2015, a total of 30,904 nurses. The number of men registered in The Slovak Chamber of Nurses and Midwives (SKSAPA) in the nurse profession was 109 in 2010. In 2014, only 37 men were registered. Currently, less than 2 % of men work in nurse profession. The following Fig. 1. shows the structure of employees working in the nurse profession, by age. [1]

Age category 50+ is up more than 1/3 of all nurses. Employees of this age begin to lose functional and working skills, including physical strength. The reduction in muscle strength is visible after the 45th year. The biceps force is gradually reduced by about 55 % in 65th year. Also, force in the wrists and the muscles of the hand by about 20 %. The loss of muscle strength is fairly the same for both men and women. [2]

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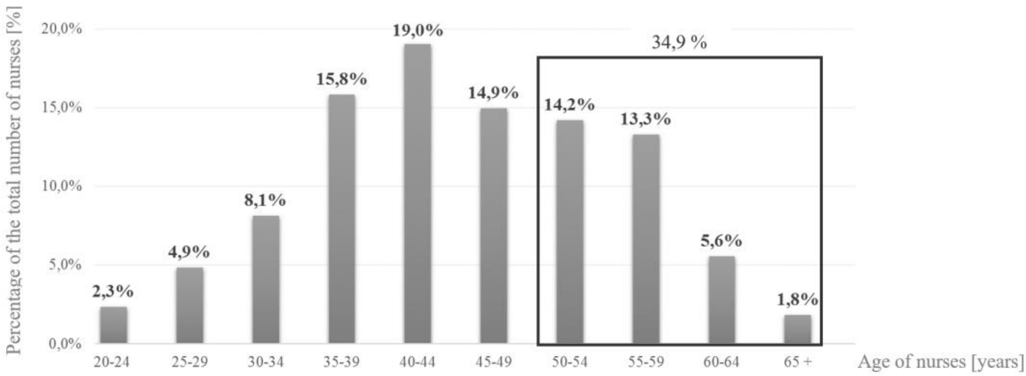

Fig. 1. Structure of employees working in the nurse profession, by age [1]

2. PHYSICAL LOAD IN WORK OF NURSE

Nurses are in their work confronted with the workload, psychological and physical load. The workload represents a certain category of overall living load and stress associated with work activities and work conditions. Work in health it is associated with greater stress than work in other professions. Excessive mental stress increases the risk of erroneous decisions and accidents at work. Physical load damages health and reduces work performance. The work of nurses in departments, where they work with partially or completely immobile patients is especially physically demanding. [2]
Facts relating to the structure of employees working as a nurse (only 2 % of men, more than 1/3 of women aged 50+) increase the urgency of the need to address the physical load of nurse work. The causes of physical load correspond to the severity of nurse work resulting from patient handling. The nurse is confronted with work in inappropriate working positions and the physical load resulting from patient handling (patient corresponds to the nature of the load per the legislation).
Work position directly affects the physical load. The same work in different work positions can cause another reaction in the form of strain. The right job choices allow only the muscle groups that are necessary. Working positions characterized by significant changes in the position of the hull and limbs are called non-physiological. These positions cause great energy consumption and, if a person is forced to work in them for a long time in this work position, there is a risk of damage to the musculoskeletal apparatus. Nurses often get to work in non-physiological working positions during their work. When treating the patient, this is the position of the forward bend, axial or lateral rotation in the torso, squat, kneeling, working with hands above the heart level. The following Fig. 2. shows some of the non-physiological positions in nurse work.

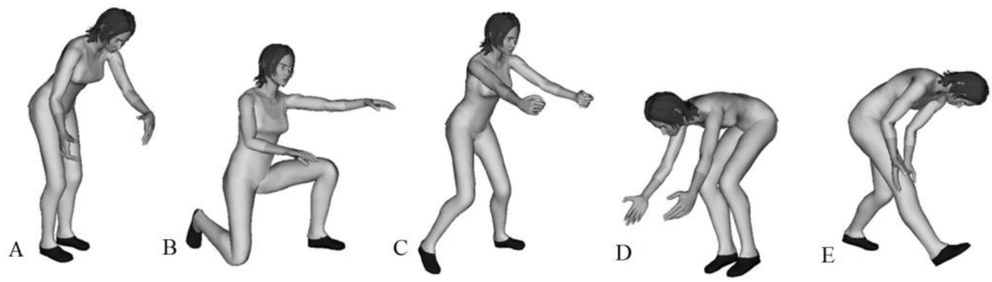

Fig. 2. Actions in which a nurse gets into non-physiological work postures: A) Positioning the patient, B) Lifting the patient from the chair, C) Placing the patient on the bed, D) Lifting the patient from the floor level, E) Damping the patient's fall

The risk of work-related health damage associated with work position is increased because of simultaneous patient handling. The weight of the patient is well above the weight limits for load handling, intended by legislation for women and men. Conditions for patient handling are considered unfavorable. The weight of the patient is asymmetrically disposed and its body does not provide accessible and firm places, for safety grasp. Therefore, is difficult for the nurse to keep the patient close to her body, as recommended by the principles of load handling. Due this is desirable to use the available handling aids. [3, 4]

3. AVAILABLE HANDLINGS AIDS

The use of handling aids, partially or completely, eliminates physical load, what is patient handling for a nurse. These aids can be divided into small handling aids and large handling aids (Fig. 3.). Small handling aids are less costly, simple means of facilitating patient handling. The method of moving using small handling aids is accomplished by means of aids such as low-friction textile sheet, ergonomic belts, rotary cushion, lift pole, etc. The transfer methods using large manipulation aids are implemented by means of electromechanical lifting devices intended for patient lifting in a lying, sitting or standing. [5]

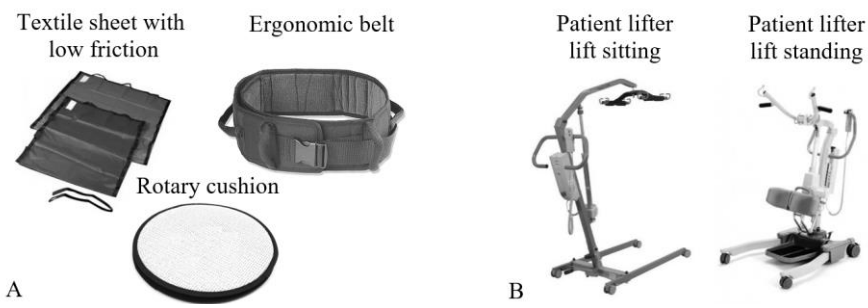

Fig. 3. Handling aids: A) Small handling aids, B) Large handling aids

Decision making on patient handling techniques is dependent on the assessment of the patient's needs and capabilities. One of the factors to consider is the level of help the patient needs. It is important to know if the patient can carry partially his own weight and to what extent. Also, the total weight of the patient is important. Weight may be too large for the nurse to be able to handle the patient safely. The patient's willingness to cooperate in handling is also important. The basis of manipulation is to inform the patient about the procedure of manipulation and to encourage him/her to cooperate if his state of health permits. Wherever possible, the use of large manipulation aids for patient handling should always be recommended. [6, 7]

4. CONCLUSION

A reaction to the high risk of injury or occupational disease in a healthcare facility would be to ensure the handling aids. If the health facility does not take care of nurses, then nurses themselves may become patients. For healthcare facilities, it will mean their absence, which ultimately reduces the quality of healthcare provided to patients and may indirectly lead to burnout syndrome of remaining staff.

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Ella Software platform, Cyber-Physical systems, Symbiotic simulation

Lukáš ĎURICA*, Michal HOČ**, Vladimír VAVRÍK***

SOFTWARE PLATFORM FOR INDUSTRIAL APPLICATIONS: ELLA

Abstract

This paper combines new approaches and views on the simulation and control of Cyber-Physical Systems (CPS) that form an integral part of the 4th Industrial Revolution (4IR). The paper describes the ability to create and simulate the physical models of the physical systems, as well as the possibility of symbiotic simulation. Ella Software Platform (ESP) includes modules to simulate and control CPS, but also exploits the potential to combine symbiotic simulation with physical modeling.

1. INTRODUCTION

The 3rd industrial revolution, based on the introduction of information technology into the production, has brought unprecedented growth and productivity. The combination of IT and electronics enabled the dawn of the automation and hence the production of higher number and higher quality products. We are at the doorstep of the 4IR called Industry 4.0 [1] (or Industry 4.0 [2]) that introduces CPS. CPS are computer-controlled mechanisms that consist of two elements: cyber, a component that possesses the computational potential, and the physical part itself. Unlike the embedded systems, CPS are typically designed as a network of interacting elements with physical input and output instead of as standalone devices.

However, for the development of such systems and applications, a platform is needed to enable their simulation, control and coordination. The ESP is a possible solution to meet these requirements.

Ella is written in C++ and its development started at the University of Žilina, Slovakia. Development continues with company EdgeCom. Its primary objective was to test robotic systems. The platform has overcome a dynamic period of the development. Today it covers a wide range of applications, from modeling, simulation and testing of various systems, both robotic and industrial, ranging from a virtual maintenance trainer, physical simulations, monitoring and visualizing conditions of autonomous logistic trucks, to the attendance system. Currently, Windows 10 is supported.

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The ESP is composed of the core and modules. Its modular structure allows the development of independent modules (toolboxes) that do not interfere with each other, but can use functionality from the common core.

2. THE CORE OF THE ESP

The core of the ESP consists of several libraries. The virtual world library contains discrete simulation tools and also allows for the management of virtual objects that can interact with each other. Changing object parameters during the simulation is matter-of-course. The ESP provides a 3D scene (OpenGL library) and a graphical user interface (GUI), supporting embedding 3D graphic formats such as .dwg and .fbx. The PhysX library provides the ability to simulate solid and soft bodies, particle effects, as well as motor joints, collision detection, or sensors (Fig. 1.).

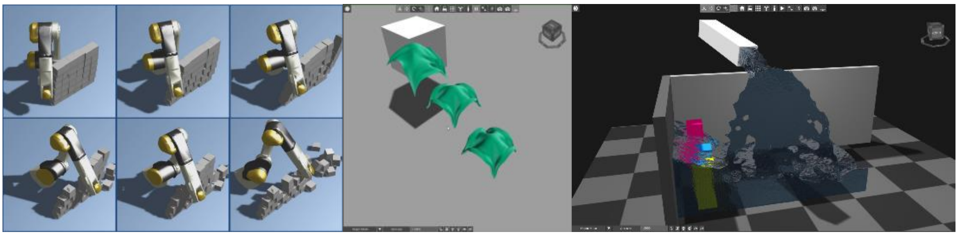

Fig. 1. Physical simulation of rigid and soft bodies. On the right side is simulation of particle effects

Mathematical library provides advanced mathematical operations for linear algebra. The PostgreSQL and SQL Lite libraries were implemented for database management. Network communication is provided by the wrapper of the Boost.Asio library. The aforementioned libraries are also written in C ++. These libraries can be used to develop modules. Thus, modules can use tools, for example, to create properties of physical objects.
In case of CPS, we can model and simulate their physical elements by physical library. To control them, we can use integrated network library. In other words, the environment of the CPS can be reflected by the virtual environment and the virtual models, taking into account, their physical properties and states.

3. MODULES OF THE ESP

3.1. Multi-agent system module

To enable the development of Factory of the Future [3], the multi-agent system (MAS) has been implemented. This multi-agent system meets the FIPA specifications (FIPA ACL, FIPA CNIP, FIPA Agent Management, etc.). [4]
The Delegate MAS (D-MAS) [5] design pattern has also been implemented. D-MAS has been successfully proven in coordination and control (C&C) applications. It contains simple, light-weight agents that and can use digital pheromones to predict the future states and several future scenarios of the system.
Symbiotic simulation [6] is a simulation that emphasizes the relationship to the physical system. Symbiotic simulation involves feedback to the physical system, thus controls it.

Simulation performs "what-if" experiments that are enriched with the data collected by the controlled physical system. The results of "what-if" experiments can be used to control the dynamic behavior of the system. Physical system benefits from this symbiosis because decisions are made in near real-time and the results of "what-if" experiments can include several future scenarios of the system behavior.
Properties of physical models and symbiotic simulation can lead to better, more accurate results, thus achieving higher performance of the system.

3.2. Virtual Maintenance Trainer and Virtual Reality HTC Vive

The module of the virtual maintenance trainer is used to train maintenance workers. It provides a virtual reality through the headset, allowing users to navigate 3D space naturally, using sensors that track the user's movement (Fig. 2.). For a worker, such an environment is much more intuitive. It provides training for industrial robots, CNC and other engineering equipment.

Fig. 2. Virtual Maintenance Trainer

3.3. Module for control of modular robotics

The modular robotic system control module includes a library of different robotic parts, such as robot bodies, legs, wheels, or nozzles. After attaching the individual parts to the robot body, the control for a given robotic assembly is generated (Fig. 3.).

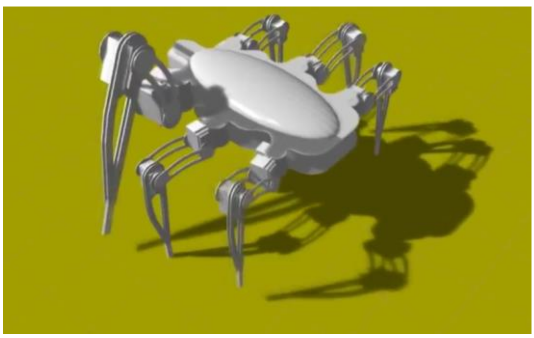

Fig. 3. Modular robotics

3.4. Module for monitoring of Automatic Guided Vehicles (AGVs)

The monitor of AGVs provides the ability to monitor the movement and status of individual AGVs. Monitor includes communication status, battery status, and status auras in a virtual 3D environment for each AGV (Fig. 4.).

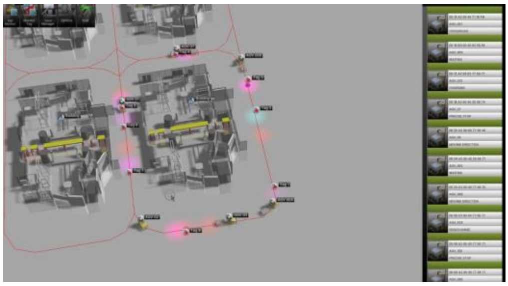

Fig. 4. Monitor of AGVs module

4. CONCLUSION

Modeling of physical objects of CPS and symbiotic simulation can lead to better, more accurate results, thus achieving higher performance of the system and enable predicting of future system states. The ESP provides necessary functionality to create such a system. A brief description of its modules is given.

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SIMULATION OPTIMIZATION OF MANUFACTURING AND LOGISTICS PROCESSES

Abstract

Simulation as a supporting tool for decision making process, analysis, optimization and forecasting is mainly used for optimization, planning and control of processes, projection and analysis of production and logistics systems, etc. The heart of simulation is experimentation with model of a system and so looking for optimal solution. This paper deals with the optimization of manufacturing and logistics processes with the support of progressive computer simulation approaches.

1. SIMULATION OF MANUFACTURING PROCESSES

If there is a simple manufacturing system it can be described by relations and quantitative variables using analytical methods. Analytical methods are too deterministic and static for solving today's complex, dynamic tasks, and mathematical models of complex systems are themselves complex, and there is excluded any possibility of analytical solutions. In such a case model must be studied by simulation.

The first step of computer simulation is to built simulation model of the production system. The next step is to perform experiments with the simulation model and achieved results are used for improvement of the real system. Simulation is a experimental method in which the experiments with a simulation model of manufacturing system are make on a computer. It also ranks among statistical methods because it works on the same theoretical basis as methods of mathematical statistic. Model includes only those characteristics of real system which the analyst is interested. After evaluation of results the analyst makes conclusions about the whole real system, based on experiments with the model. Simulation overcomes many boundary conditions and limitations of analytical modeling techniques and its use is justified especially in those cases where other possible solutions have failed. It is also an important element in workers' training.

1.1. Parametric simulation model

External information system is often source of data for simulation model. It allows easy transfer and data processing, and it facilitates manipulation with data in database of the model.

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Parametric simulation model is a practical tool for finding problems' causes of the selected type of manufacturing systems, created for selected input variables. After modeling and entering the specific characteristics of production system (such a service time for each workstation, the way of parts arrival to the workstation, the transportation size, the way of manufacturing system control, etc.) can the process be simulated with sufficient precision. The analyst can also directly see critical points of production process and simulate various possibilities for their removal. The obtained results, in the form of tables or graphs, are after execution of simulation experiments automatically transferred to external information system and on their base optimization of real system can be done. All this can be carried out without detailed knowledge of modeling and simulation methods and without deep knowledge about simulation software [1].

1.2. Emulation

Apart from production planning management, production management requires current information about real manufacturing process (feedback from the manufacturing process) in a real time. The systems collecting data from a manufacturing process inform about the current states of production facilities. They also provide an opportunity to intervene in production process and affect it, to change real system's settings on computer.
The emulation means connecting a real system with its parametric simulation model and loading the data directly from a real system into a model database (possible by using sensors connected via a control unit in computer). In addition to simplify data handling this system allows to change settings of a real system (a vector of input factors) on computer using excel interface which eliminates need for knowledge of simulation program. Fundamental of emulation is that the simulation model is a substitute of real, missing module, respectively elements of comprehensive simulation model are gradually replaced by real devices.

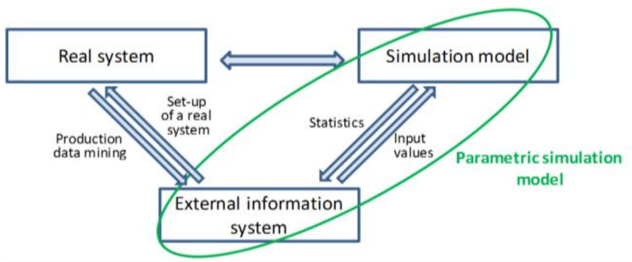

Fig. 1. Emulation [4]

The main advantage of this purpose is rapid determination of the effect of changes in guiding principles of production on a virtual model, which is in direct connection to the real production system. Emulation environment can monitor production respectively logistic system, evaluate collected data in a real time, update the model on the base of data from a real system, and execute experiments on accurate, updated and verified simulation model.

2. OPTIMIZING SYSTEM FOR MANUFACTURING PROCESSES

Optimizing system for manufacturing processes - OSMAP is concept developed at the Laboratory of Intelligent Systems – ZIMS (common workplace of CEIT and University of Žilina), This concept covers modern approaches and tools for simulation through the use of emulation and software as a service, to own computer applications based on Genetic Algorithms (GAsfoS, GAsfoS2), scheduling of custom production (SSEM) and metamodelling (SAGME).

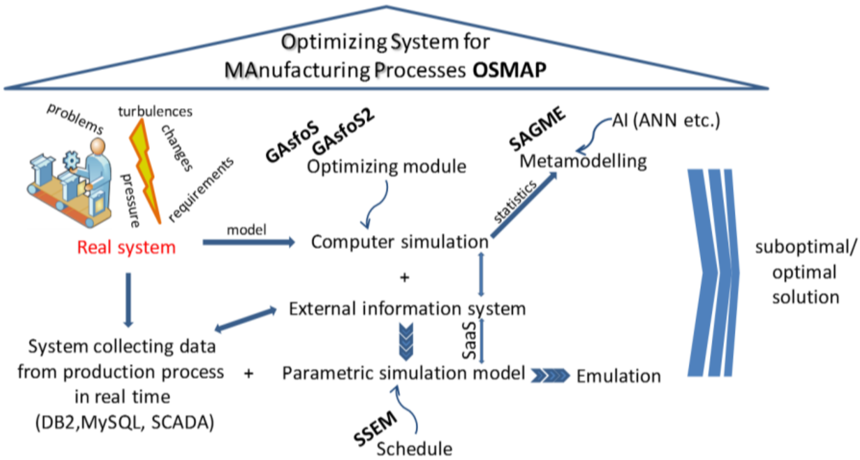

Fig. 2. Concept of the OSMAP system [4]

SaaS - The target is delivering software as a service (SaaS), in this case simulation software. It means that customer's data are stored in "cloud" in databases placed on server on the internet, and users can access to them through web browser or client application and use them practically anywhere. [4]

GAsfoS2 - The simulation optimizers that can be a part of simulation program or can be in-programmed help on a large scale for simulation optimization. GAsfoS2 application is based on genetic algorithm (GA) and it is able to optimize whatever production system.

Simulation And Scheduling – SSEM – (Scheduling using Simulation and Evolutionary Methods) is modular system for scheduling of custom manufacturing with support of simulation and evolutionary methods.

2.1. Simulation Metamodelling – SAGME

In a state of simulation results acquiring it is possible to simplify, combine inputs from simulation, and eventually eliminate those that have shown to be needless. This enables so called metamodels or models of simulation models that substitute simulation data with function curve and reliably approximate them. This approach was named as approximation control. It is based on replacing of empirical data with suitable type of theoretical function that realistically describes authentic data acquired from a system or from the simulation. Our system for automatic generation of metamodels SAGME was created for such purposes. The system SAGME consists of five modules:

- module for data collection,
- module for variables' dependences detection,
- module for calculating of metamodel parameters,
- module for error calculating,
- module of total reports.

The SAGME system enables well-arranged simulation results in form of contingent tables and charts, recovery factors with the strongest influence on monitoring responses, function parameters accounting, metamodel validation in regard to simulation model, and all received results summarization into synoptic charts. On their basis it is possible to define approximation rate of accuracy, to accept metamodel or find better solution.

3. CONCLUSION

These progressive approaches afford opportunity to use simulation in terms of practice easier. They can flexibly respond to customer's requirements and provide them a tailored service, and enable rapid use of simulation in the commercial sector, not only in terms of research. The above mentioned progressive simulation approaches allow:

- to easily enter own values of elective variables (loading input data from an external source),
- to operate parametric simulation model by managers and operators in production shop,
- to test various managing and optimizing methods without deeper knowledge of modelling and simulation methods, and simulation software,
- to execute simulation runs and process optimization without possession of simulation software,
- to find the best solution of company problems in a very short time,
- to save financial resources.

The approaches described in this paper focus in the improvement of companies' interest in simulation of manufacturing and logistics systems.

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Internal logistics, Dynamic simulation, Interactive projection system.

Radovan FURMANN*, Beáta FURMANNOVÁ**

LOGISTICS AND DIGITAL TWIN

Abstract

When planning logistic systems, it is very important to interconnect the real data from the control systems of logistic resources with the monitoring system. Subsequently, interactive design takes into account actual requirements of the real systems. In the article is described methodology of interconnection of the real logistic elements with interactive projection planning system and process simulation.

1. LOGISTICS

Logistics is increasingly the motor of success of industrial organisations on global markets. Globalisation brought not only the potential of global market, disturbance of market barriers and free movement of capital, but also global competition and so far unknown speed by which market turbulences appear. The current effort of modern logistics systems projectants is, when designing these systems, to build into their features the ability of fast adaptation to changing market conditions. These systems are, at present, called adaptive logistics systems which use, for the ensuring of adaptability, new types of technologies also on the basis of computer emulation.

Reconfiguration of logistics, as well as adaptability, is based on the current need to project logistics concepts in smart factories. Logistics systems are made of hardware, software and peopleware elements. Digitization in 21st century has dramatically increased importance of software. The dynamics of digitization, the huge growth of computing power, miniaturization, development of software services, related to the use of artificial intelligence, Internet of things and clouds enabled implementation of the intelligent elements directly to the logistics facilities (called nested intelligence).

The second decade of 21st century brought another revolution change. Modern real factories, using the most advanced technologies, as denoted as Smart Factories. This paper reacts to the rising need to project intelligent plants with reconfigurable logistics systems. Adaptive logistics system currently use great amount of data. Given amount of data about internal and external factors, formed as a result of massive use of sensors, allow to process new technologies for Big Data. Extraction of information and knowledge from data brings the new era of knowledge engineering, when the knowledge is not created by a man, but they are also the result of data processing by information systems.

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Software and software services and their development became the condition for the further development of logistics. Software services represent nowadays the crucial factor of competition ability of logistics solutions. It can be seen literally on every step. Pallets, containers, conveyors, robots, mobile robotics, reservoirs, storages - these all become intelligent and able to mutually communicate and make decision. Software therefore gradually becomes the thing which decides about the amount of added value which is created by logistics and which becomes the part of added value of product. Software and software services therefore directly become to affect the quality and price of products. By connecting the dynamic simulation (digital world) with real logistics systems (real world) through intelligent sensors (virtual world) will create the complex solution which will reflect on the requirements of industrial plants to build so called intelligent production and logistics systems.

2. DIGITAL TWIN IN LOGISTICS

Technological concept Digital twin is functional system for the continuous optimization of logistic processes and it is formed by the connection of real logistics with its own digital "copy". It creates an environment of digital factory, in which the company can optimize the logistics directly during the production process, change the parameters and configuration of logistics in real time. Data that arise during this time form a comprehensive picture of the logistics. Data are collected and continuously evaluated by the Digital twin. Among other things, this allows to shorten and streamline material handling process, optimize logistics processes and performance of the staff that ensure logistic processes.
At the Department of Industrial Engineering, University of Žilina in cooperation with technology partners CEIT and EdgeCom we develop our own approach to reconfigurable logistics, as shown in Fig. 1.

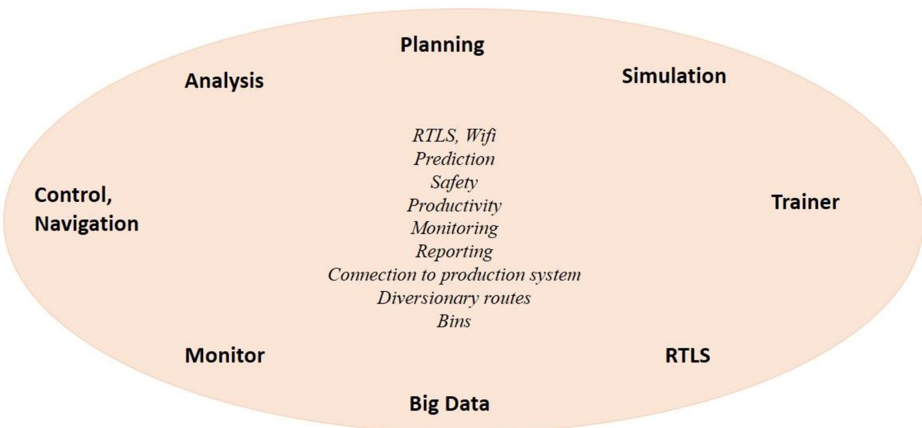

Fig. 1. Digital Twin Concept KPI, CEIT, EdgeCom

Technological concept Digital twin is deployed mainly in the automotive industry where it is currently tested by the companies CEIT and EdgeCom. This concept will play important role in the future intelligent manufacturing systems, where manufactured product will behave as an intelligent entity in the production. This entity will be capable of communication with its surroundings and will be able to organize its processing fully autonomously. Such a product will itself determine the sequence of its processing will allocate the required capacity in the competence cells and will call in mobile robotic systems, but also conventional logistics resources to ensure its transport in the production. Therefore it is important to create virtual copies of real elements of production and logistics systems, which will be based on the relative autonomy and their behavior will be similar to behavior of intelligent, living organisms.

This concept must be based on planning, which is currently provided by the interactive projection-planning system. This system represents intuitive, team-oriented design of logistics systems. It is based on a technology platform Ella, which is integrated in the whole chain of Digital twin concept. Projection planning system includes evolutionary algorithms, which represent a new way of solving complex optimization problems in logistics. Mentioned problems are too complex for traditional computing techniques, and they do not provide useful results, or are not applicable at all. These algorithms use heuristic methods and stochastic phenomena, while finding optimal or sub-optimal solution for logistics concept. [4]

If the production system layout connected to the created logistics concept is designed, then it is necessary to evaluate this solution in terms of influence of random variables representing phenomena occurring in the real world. The Digital twin concept includes emulation models that operate on the basis of dynamic simulation. Using these models we can check the behaviour of the real logistics facilities, which are connected with control systems by sensors and in virtual environment we can emulate the effects of virtual entities that may work in logistics system in the future. Future logistics will therefore be represented by two worlds, the real world and its virtual image, also called the virtual world. These worlds will be mutually integrated through data. Data on logistics activities will be collected and processed in real time. Therefor information about each logistics facility will be available almost immediately, what it is doing, its current status, what it intends to do, what it lacks and so on. The status of each logistics facility will be scanned immediately and processed information will be sent to the control center.

In order to link the virtual world with the real world control systems it is necessary to use sensors from the simplest to the most intelligent. Static sensors had been used in logistics in the past (for example capturing information if the pallet is in its position, and so on). These sensors had been connected to control system by wire. Interconnection of sensors and control systems is now called sensor networks. Later on, static sensors have been replaced by wireless sensors. These could be placed on mobile logistic resources and thus was created Mobile Wireless Sensor Networks - MWSNs. Those networks already support the concept of holonic control. This type of control checks and monitors all logistic processes. Various classes of sensor networks and generations of sensors, respectively tags have been developed.

Based on monitoring systems RTLS - Real Time Location System it is already now possible to dynamically change the robotic logistics trucks on predefined logistics circuits. Using the technology for monitoring the movement of objects in the defined space and in real time in connection with a dynamic parametric model it is possible to emulate the behaviour of the real world based on pulses from the virtual world. The obtained data from the RTLS system form the raw material for further processing with Big Data methods and technologies. Algorithms in the Digital twin concept are able to search for "invisible" connections and relationships in the existing data, and to use them for prediction and decision making support.

These algorithms are intelligent and therefore they are referred as Smart Data. Using the mapping editor, in combination with virtual simulator it is possible to train the logistics stuff that will be assigned to carry out logistics activities in a virtual environment, while they are affected by real monitored logistics equipment. Using the digital twin concept it is possible to navigate conventional logistics equipment to its destinations and to predict the behaviour of real logistics system. This prediction may be entered by the data from analytical phase. This data can be verified retroactively to find collision logistics activities in it, that may significantly influence designed logistics system in the future. [2,3]

3. CONCLUSION

The digitization in the 21st century brings with it the need to design intelligent logistics systems. Virtual world is interconnected through smart sensors with the real world representing real logistics system. This interconnection is ensured by Digital twin technological concept, which is currently intensively developed at the Department of Industrial Engineering, in cooperation with CEIT and EdgeCom

At CEIT company each project linked to the implementation of logistics robotic systems - CEIT AGV is supported by digital design, which is subsequently dynamically verified. Therefore, based on experiences in the implementation of intelligent logistics systems using digital twin, it will be possible in the future to affect up to 80% of the costs related to the preparatory phase of the solved project in logistics. Importance of digital technologies is increasing significantly nowadays. Therefore, future logistics systems will be massively supported by technologies stemmed from the Industry 4.0 technological revolution, such as already mentioned Digital twin.

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Human resources, Education of employees, Training centre.

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EDUCATION OF EMPLOYEES IN COMPANIES

Abstract

Development of human resources in work process is closely related to so-called company education. Education and working skills of employees are becoming a decisive force of development and strong features of every successful company. It is clear that only those companies which realise the importance of human factor and the ones which are ready to invest in development of education and working skills of employees can afford implementation of business aims, market status and a favourable position among top-level companies.

1. COMPANY EDUCATION

Human existence has been suffering from and followed by traces of discomfort and insufficient dissatisfaction for ages. Every day of people´s life, there was at least one unpleasant situation that they had to face and pay attention for a while. That actually happened from their childhood to death. They were thinking hard how that could have happened, but more important, they were forced to think of sorting it out.

Company education is focused on adults. Main goal is to reach a competitive advantage by a strategic placement of skilled and loyal employees. Regardless the extent or form the company decided to invest in development of its employees, it is recommended to use a systematic attitude to education that ensures support of achievment of strategic company goals connected to company culture and employee orientation.

Systematic education represents a repeating educational cycle, whose results are obtained in longer time period. It passes through four basic phases that are shown on the Fig. 1. At the beginning, it is necessary to collect all information related to current status of knowledge and skills of employees and to define required levels. Consequently, it is moved to educational planning (creation of specific educational program with its exact goals, method, content). After completing preliminary phases, we fluently continue to realisation of educational process and its evaluation. [5]

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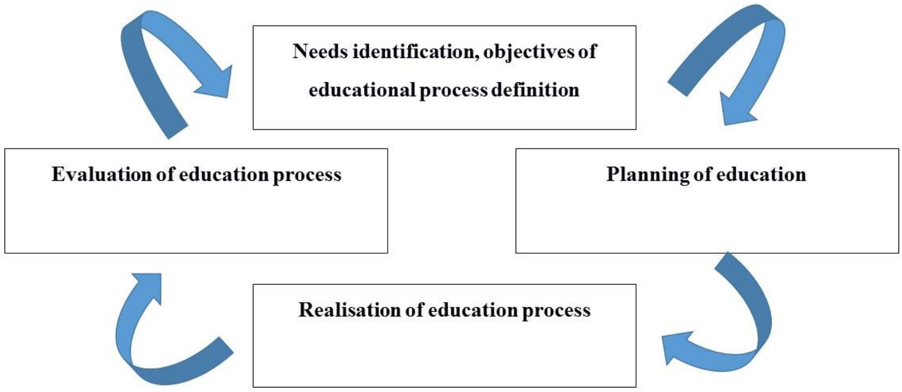

Fig. 1. Cycle of company systematic education [5]

Kachaňáková defines education of employees as a permanent process, where adaptation and change of working behaviour, level of knowledge, skills and motivation of employees by learning on the base of different methods´ use occur. The result is a decrease of difference between real competencies of employees and requirements claimed on them. According to [3] company education should be focused on area of qualifying preparation by means of the activities like adaptation (orientation), deeper qualification (training) and requalification (retraining).

Key question from the point of a successful education is the choice of an educational method, that depends on various factors, as goals of education, content, insistence, disposable sources of education, etc. The most common methods of education are [1]:

- demonstration – trainer shows a certain activity and trained person has opportunity to try it. However, by more difficult activities, it doesn´t ensure convenient structural acquisition of new knowledge and skills,
- coaching – a method based on relation between manager/team leader and employee. The method is usually carried out informally, as a part of common management process. Experienced leader continually guides trained person , though he leaves the space for his/her own processes of recognition and examination of problems,
- mentoring – especially chosen mentors offer advice on demand to persons in charge, nevertheless the advice is often related to creation of personal plan development, various inter-major direction and so on. The mentor is chosen by trained person him/herself ,
- fluctuation of working places – by good planning and managing, it leads to extension of trained person skills and to understanding broader relations of proper work as well,
- task charge – trained person is given a specific task, which he has to solve by audit of experienced worker or trainer ,
- self-learning or coordinated reading – trained person can be asked or led to self-learning of a certain company or external materials and documents,
- e-learning – it is actually a new progressive form of education that often uses a combination of other educational methods with application of modern multi-media technology,

- lecture – it is less interactive method of education which is applied mainly in case of big number of trained people (suitable for example for intimacy with certain information, easy to understand),
- training – a highly effective method of education, where experienced trainers with a group of at most 5-10 people carry out various exercises, simulations completed by theoretical explanation,
- outdoor learning – it is a very popular method in application of modern human resources management, focused on team-building, knowing ourselves and the others, identification of team roles, etc., while it is carried out by shorter or longer motional and sport activities (in particular the ones where success depends on team cooperation) under leadership of experienced training managers.

1.1. Training centers

In recent years, the opening of training centers has become popular, where the employees can be trained or retrained in new areas. It is the most applicable in bigger companies. Whereas, it is necessary to fulfill the following conditions:

- **WHAT** – training preparation to adaptation of new skills,
- **WHO** – group of employees (2-5 people),
- **WHEN** – before starting new activities or by changes of existing process,
- **HOW** – detailed intimacy with theoretical knowledge of certain area or practical exercise (repetition of operations until the activities become intuitive and automatic),
- **WHERE** – personal space separated from real workplace to prevent disturbing environment influences, which decrease ability to learn and get new knowledge,
- **WHY** – to be informed more closely and learn new standard working processes, to ensure performance of production actions and operations in practice automatically and without hesitation, to cut variations in implementation of actions in production process(increase of production and quality, decrease of failures, decrease of operating times).

At the beginning, it is necessary to have an available training room, equipped by modern training facilities and materials as for example. visual boards, flipcharts, computers together with presentations containing theoretical information of specific problem, instruction videos with working processes and instructions, training machines (according to the type), production documentation – only for purposes of training center (orders, drawings, technological processes, instructions to control, card of measured values, regulation cards...), measuring tools and measuring devices designed for control and alike.

Fig. 2. Demonstration of training in training center [4]

2. CONCLUSION

Every employee who wants to get or keep working position in a working team of a successful company must try to keep up his/her knowledge and practical experience at the level of current time. From the point of the company, it is inevitable to afford place and conditions for professional and personal development of every employee.

Education, formation of working skills, application of customs and skills obtained by education and their use in professional practice have become lifetime process of modern society. Recently, there has been assumed an importance of education of individuals, support and enforcement of individual education as well as creation of that environment where this knowledge is being developed and systematically managed. Investment in quality of education represents main factor of human resources development and whole development at all.

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Operator 4.0, Logistic systems, Production systems, Digitization, Industry 4.0

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EMPLOYEES FOR NEW PRODUCTION SYSTEMS

Abstract

The article presents the usability of new knowledge in the next direction of research in the area of designing a complex logistics system in production. If factories fail to provide their products at the right time, in the right quantity and at the right price in these times of growing online business, they can no longer satisfy their customers' Complex requirements of Logistics system in production. The Industry is facing increasing pressure for optimization. Many factories have not yet recognized that Industry 4.0, the Internet of Things, Big Data, Digital Factory and collaboration are more than just marketing buzzwords.

1. MODERN APPROACH IN FACTORIES

Industry 4.0 will continue to transform classical manufacturing systems into Intelligent Manufacturing Systems (IMS). This will have significant implications on the nature of work in industry as Industry 4.0 will transform design, manufacture, operation and service of products, production systems, employees and operators. At the same time, the demography is changing, especially in Europe and Japan, which brings forth additional challenges for manufacturing companies. Increasing immigration may relieve some of the effects of demographic change. However, integration of new migrant workers with a high variety of technical skill and educational levels and different culture is considered a great challenge. Therefore, is necessary to begin with concept of Operator 4.0 already nowadays. [1]

The distribution logistics is currently undergoing a paradigm shift. First and foremost, the change is driven by the market itself: Food and non-food consumers have completely new possibilities to cover their needs with E-Commerce and online trade. The good old supply chain has long developed to a consumer-controlled demand chain. Moreover, technical developments such as Big Data, Predictive Analytics, or Smart Logistics (4.0) create the conditions to practically realize concrete solutions for partially new business models. [2]

Tomorrow's supply chains will be intertwined supply networks predicated on responding to supply and demand changes as they happen, not after the fact. Transaction and shipment exceptions are common, so businesses must be able to account for these variables by enabling a proactive supply chain. When problems occur, the earlier and faster information is

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communicated to partners, the better they can work toward finding an efficient and economical resolution. [3]

2. DIGITIZATION HOW AN OPPORTUNITY FOR FACTORIES

Companies in years 2009 - 2010 experienced unfavorable conditions: the financial crisis has exposed their structural weaknesses that had to be remedied if they wanted to survive. Many companies have achieved this, they change their policy. But many companies also did not succeed. The world has already digitalized in a so called "simple areas". Today is the turn of industrial companies and their processes. Customers will in future expect easy and seamless cooperation. And why should be industry companies occupied by the digitalization? Here is a small example: every minute is in Apple's App Store downloaded 48,000 applications. Every hour is to internet connected 5 million devices. Every day it is created so much data, as shown in the cradle of our civilization until year 2003. The products that customers want to buy on the internet they look at least 10 times and then contact possible suppliers. And when they do, it is often discouraging, if they cannot confess at the sellers home page or find the right product or person. Digitalization opens the door to great opportunities. [4] The digital future will combine the products with the software solution, which is already happening. Advantages can be already seen in maintenance. If companies have in their software right information and can trust them, then handyman can already be prepared in advance to failure, planned maintenance or patrol. This reduces implementation times and improves the work efficiency of maintenance workers and thus less production will be shut down. Digitization is a big organizational change in factories and in society. That is why workers must have new skills and knowledges. [5]

3. EMPLOYEES IN SMART FACTORIES

The Fourth Industrial Revolution will continue to transform the industrial workforce and their work environment through 2025 and beyond. This will have significant implications on the nature of work in industry as Industry 4.0 is transforming design, manufacture, operation, and service of products and production systems. At the same time, the demography is changing, which brings forth additional challenges for manufacturing companies. As a consequence, manufacturing enterprises, and in particular ‘smart factories’ as socio-technical systems, will need to form and adapt a social perspective to be proficient in assisting ageing, disabled, and apprentice operators. [6, 7]
Advanced industrial engineering, advanced digital and industrial technologies will help people to remain in, return to or be incorporated into the modern manufacturing workforce. Meanwhile, developments from a technical perspective, new connectivity enablers and interaction technologies among components (smart products), machines (smart machines) and humans (smart operators) will make production systems more lean, integrated, agile, traceable, and adaptable. [8]

3.1. Type of Operators for Industry 4.0

Technologies of Industry 4.0 can assist operators to become ‘smarter operators’ in their future factory workplaces. Furthermore, it is important to mention that these types of Operators 4.0 may exist on the shop-floor as either single- or hybrid- types. A selection of various augmentations of the original human capabilities are presented below; note however, that there might be multiple other aspects that are part of the Operator 4.0. Those augmentations do not only come in a variety of levels but also can be combined. It is also very likely that the future Operator 4.0 may only be augmented in one specific area whereas the other aspects are neglected. In some cases, that will not even be possible (e.g. augmented reality functionality necessarily needs a ‘connected operator’ to perform). Type of Operators [9]:

- Super-Strength Operator: Operator + Exoskeleton (physical interaction),
- Augmented Operator: Operator + Augmented Reality (cognitive interaction),
- Virtual Operator: Operator + Virtual Reality (cognitive interaction),
- Healthy Operator: Operator + Wearable Tracker (physical and cognitive interaction),
- Smarter Operator: Operator + Intelligent Personal Assistant (cognitive interaction),
- Collaborative Operator: Operator + Collaborative Robot (physical interaction),
- Social Operator: Operator + Social Networks (cognitive interaction),
- Analytical Operator: Operator + Big Data Analytics (cognitive interaction).

The following Fig. 1. shows an example of how Operator 4.0 will working in Factory of the Future.

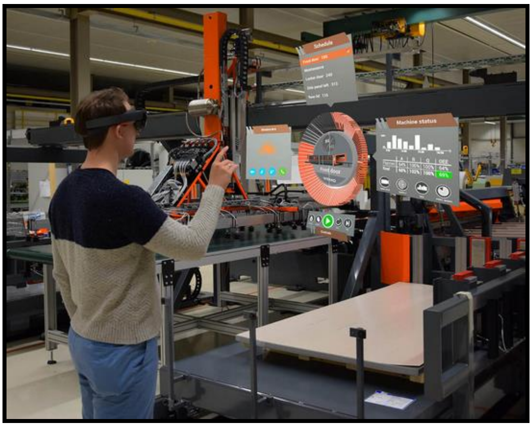

Fig. 1. The worker sets up a production line with augmented reality

4. CONCLUSION

The aim goal of this article were description of employees for new production system. Human-centric manufacturing has been a core topic for most previous manufacturing paradigms. Nowadays that same is true for Industry 4.0. University of Zilina systematically coordinate research activities with special focus on needs of European industry. Since 2000 the University of Zilina invested big amount of money into research focused on digitalization, reverse engineering, rapid prototyping and digital factory. One of new development line of research is Intelligent Manufacturing System (IMS). New intelligent manufacturing systems will require new skills by workers. Based on this University of Zilina focuses on innovative education of students.

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Digitization, Digital maintenance, Industry 4.0, Adaptive production systems

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DIGITIZATION OF MAINTENANCE ACTIVITIES IN ADAPTIVE PRODUCTION SYSTEMS

Abstract

The goal of this paper is digitization and it is disrupting manufacturing by using innovative approaches and agile business processes to optimize end-to-end manufacturing value chains. The article focus on a novel approach to Total Productive Maintenance processes that leverage three essential digitization forces: Internet of Things, Big Data Analytics, Transformation process and Adaptive Production Systems. The disruptive digitization approach to maintenance from descriptive, to predictive, to prescriptive with digitized decisions, cases, and IoT applies to some industry.

1. TRADITIONAL MAINTENANCE MEETS THE FUTURE

The holistic approach to maintenance is now augmented with Things (making up the Internet of Things) that are increasingly intelligent and responsive. This advanced holistic approach offers significant advantages over using traditional (descriptive), preventive, or predictive models individually. Traditional maintenance tends to be reactive-responding to failures in equipment or devices after the fact. This traditional, reactive approach of describing failures after they've occurred (productive maintenance) is the worst-case scenario for maintenance: reacting to failures in equipment or devices after the fact. Preventive maintenance empowers operators to carry out continuous maintenance. A disruptive model harnesses the power of connected devices and the Internet of Things in a way that changes the dynamics of conventional Total Productive Maintenance (Total Productive Maintenance), which defines maintenance as simply minimizing machine downtime. Incorporating intelligent software into these connected devices (Things) is proving to be a key enabler for diagnostics and proactive maintenance.

Production systems are waiting revolutionary changes and their design will no longer be possible without the use of advanced technology and adaptive systems. Future production systems must have completely new features such as: self-organization, reconfigurability,

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autonomy, self-optimization, self-replicability, learning ability, and autonomous work with the creation and use of knowledge. [1]

2. THE ROLE OF BIG DATA

Increasingly, Big Data is becoming "Thing" Data, with connected devices in manufacturing value chains generating enormous amounts of information. Potentially, sensors on edge devices can continuously record their behavior and status. These event data are filtered and aggregated in Big Data repositories managed through NoSQL databases. Big Data analytics are then used to prescribe maintenance tasks executed in the context of dynamic cases. Data mining and discovery from Big Data allows proactive diagnostics and fixes that often anticipate and prevent incident events, which would otherwise require expensive maintenance processes. [2]

2.1. From Total Productive to Digital Prescriptive

Total Productive Maintenance is an important phase in the overall end-to-end product manufacturing lifecycle. Total Productive Maintenance has its roots in the Toyota Production System, and historically it has focused on improving OEE in the plant. The objective of Total Productive Maintenance is to create a self-directed team environment to engage employees in preventing equipment breakdowns, which ultimately leads to improvements in product quality and the ability to meet commitments to customers. Embedded sensors, software, controllers, and connectivity are creating a digital revolution in manufacturing and aftermarket services, such as warranty and repair. Breakthroughs in networking, edge and fog computing, cloud technology, faster CPUs, cheaper memory, energy efficiency, and miniaturization are all converging to create low-cost processing power and data storage everywhere. [3]

The fact is that there are now computers in machines, wearable devices, and smart Things that stream data about their operations, performance, and conditions. These Things will generate exponentially more data than people or applications. Translating all of that data into insights and intelligent decisions is the key to effective analytics. Manufacturers have an obligation to mine, leverage the detected patterns, and act (prescriptive) to avoid potential failures that could sometimes have serious consequences for people, the environment, and equipment. Business rules, business logic, Big Data analytics, and algorithms are all important aspects of maintenance optimization that spans "Productive," "Preventive," "Predictive," and most importantly "Prescriptive." The intersection of all these elements brings us to the power of digital prescriptive maintenance. Without prescriptive maintenance, we pay an increasingly high price for the waste and lack of coordination between Things, people, processes, data, and technology. [4]

3. PROCESS OF EVERYTHING

Process of Everything will be managing of dynamic end-to-end dynamic cases involving people, applications, trading partners and Things (including Robots) as participants. Digital Prescriptive Maintenance leverages the intelligent business processes with decision management in automated dynamic cases, involving IoT devices as participants. More specially, with Digital Prescriptive Maintenance manufacturers gain access to the capabilities that follow. [5, 6]

3.1. IoT Diagnostics

Things will either have on-board CPU and execution capabilities or be able to connect (e.g., via Bluetooth) to a device that has on-board execution for the device or Thing via low power connectivity. Diagnostics will support:

- Automatic Updates of On-board Device Software: Manufactured edge devices often have sophisticated software that can be updated remotely by the manufacturer.
- Automatic Sense and Data of Measures from Edge Device: A manufacturer might need to gather data from the device or ping it for specific measurements and analysis.
- Automatic Control for Maintenance: Devices can also be controlled remotely or through on board decisioning software.

Once the repair, diagnostics or replacement are completed, the Operation Center of Maintenance can validate the fix and compliance to the warranty management policy. These use cases clearly illustrate a new disruptive dawn in manufacturing through Digital Prescriptive Maintenance.

4. PROCESS OF TRANSFORMATION

The manufacturing industry has come a long way from the mechanical processes introduced by the Industrial Revolution, and has enjoyed the efficiencies of decades of computerized manufacturing processes. Even greater benefit is promised, however, as we move into the era of digital information revolution. Valuable data is proliferating, and manufacturing must harness it to reach the next level of competitiveness. It is clear that the manufacturing industry will transform as the result of the inevitable digitization of many production processes.
Digital Maintenance will be transforming and disrupting manufacturing processes. A key requirement for truly successful digital transformation of IoT is the end-to-end digitization of processes and drawing up of methodology of transformation. On Fig. 1. is such a methodology.

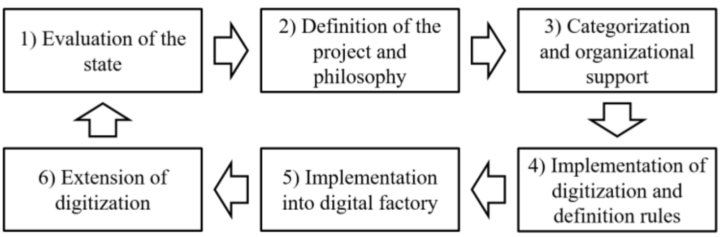

Fig. 1. The phases (steps) of digitization of maintenance activities

Digital Transformation will be discovering patterns in Thing Data and then operationalizes those patterns in digital processes. Sometimes as these events occur, they must be correlated in real-time analytics. Based on either predictive analytics models or real-time event correlation, a digital transformation solution can take action or suggest the next-best-action to humans or smart Things (e.g. robots). [7]

5. CONCLUSION

New trends in digitization and Adaptive Production Systems have begun to disrupt the classical manufacturing and industrial economy. A shift in business strategy is required to stay ahead of the curve. Digital Prescriptive Maintenance is replacing the old manufacturing practice of Total Productive Maintenance, and provides the capability to create faster, better, and more value for the customer with reduced cost. The new value paradigm demands a fresh look at supply chain and shop floor activities to include the Internet of Things, especially through the Process of Everything. Manufacturers need to be able to quickly analyze real-time events and act upon discovered models from Big Data within the context of end-to-end dynamic cases.

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Modelling and simulation, Improvement of manufacturing processes, Food industry

Ewelina HAŁAT*, Sławomir KUKLA**

IMPROVEMENT AND VISUALIZATION OF MANUFACTURING PROCESSES IN THE FOOD INDUSTRY

Abstract

The paper presents a project related to production systems visualization in food industry. The article presents issues relating to planning, improvement and assessment of manufacturing processes flow variants based on a simulation experiment. Thanks to the use of modelling and simulation of production systems a digital model of the analyzed work system has been created.

1. INTRODUCTION

A popular approach for the improvement of material flows in enterprises becomes so called "lean manufacturing". Lean Management, Lean Production, Lean Manufacturing are the notions which become about restructuring of production processes towards their simplification, slimming by combining and reducing functions and resources, minimizing inventories and delegating tasks by managerial units to teams of employees dealing directly with manufacturing processes [1, 5]

An effective tool aiding decision making on different stages of company management is the modelling and simulation method. Modelling and simulation of production systems is a method which enables for fast analysis of different variants of a production process on a prepared computer model of the system. The model which is used for simulation research is created on the basis of a real object or concept of the designed production system. A computer model presents mutual relations and behaviour of particular system elements.

On the basis of a real, existing or designed system a computer model of the research object is created, on which simulation experiments are conducted (Fig. 1.). A computer simulation model includes logic in its structure, which presents behaviour and mutual relations of particular system elements and the data which represents the characteristics of the system components. System's functioning is presented graphically by animation, and after a simulation is carried out, we obtain results in form of reports and a set of statistics illustrating, among others, the engagement level of the accessible production resources, the size of buffers, employees' workload. In case of modelling of production systems, one of the main

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tasks of models is to facilitate decision taking and setting unknown features and system's parameters [2, 3, 4].

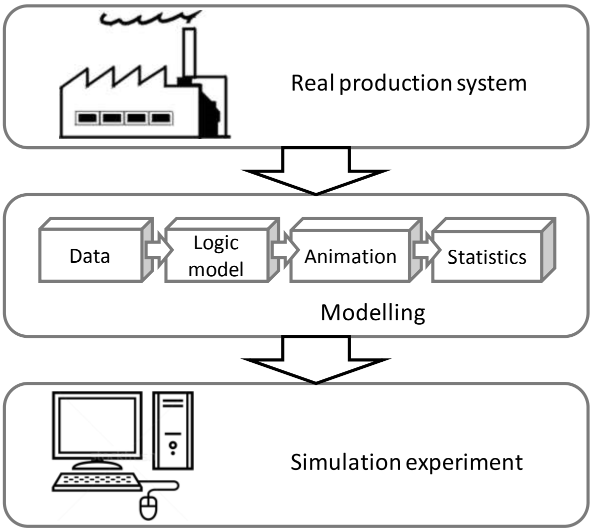

Fig. 1. Modelling and simulation of production systems [on the basis 2]

2. PRESENTATION OF RESEARCH RESULTS

The object of research in the study is a company operating in confectionery sector. Over the past few years, the company has carried out a number of necessary renovations and investments in order to be able to offer products of the highest quality, as well as delicious and traditional taste. Among others, there are cakes, cookies and layer cakes in a wide range of confectionary products of the company.

The manufacturing process of cheesecake with peaches was analysed in the study, as this cake is produced in large quantities and its manufacturing process has a significant influence on functioning of the entire company.

The summary of variances formed in the analysed process was developed on the basis of data of a one quarter period.

The main problem, which turned to be high baking temperature, was defined. The Pareto-Lorenz diagram, presented in Fig. 2., indicated the direction in which corrective actions should be undertaken in order to obtain the maximum effect, and which causes of problems do not have a significant influence on appearing abnormalities.

All possible causes of the phenomenon considered were analysed and the main categories of possible causes were determined. "Brainstorming" was an effective technique of gathering information in the team. The review of the results of brainstorming enabled categorization of causes to appropriate categories and the Ishikawa diagram was created on this basis. Applying the Ishikawa diagram helped mainly to separate effects and causes, and to discern complexity and comprehensiveness of the analysed problem. It allowed to visualize the problem along with possible areas of its causes in an easy and clear way.

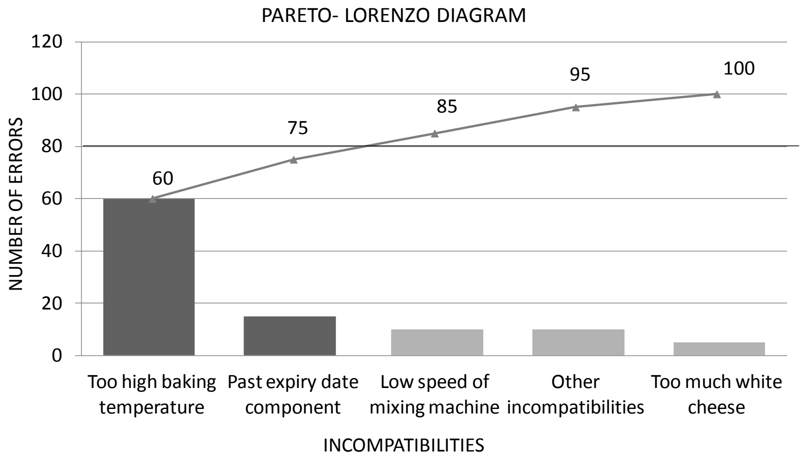

Fig. 2. Pareto- Lorenz diagram [own work]

The 5 WHYS principle (Fig. 3.) helped to quickly resolve the problem. By asking "why" key questions, the company found the cause of the problem and was able to introduce corrective actions. There are a number of causes at the grounds of most technical problems and their effects with multi-dimensional consequences, and therefore manufacturing processes should be continuously improved.

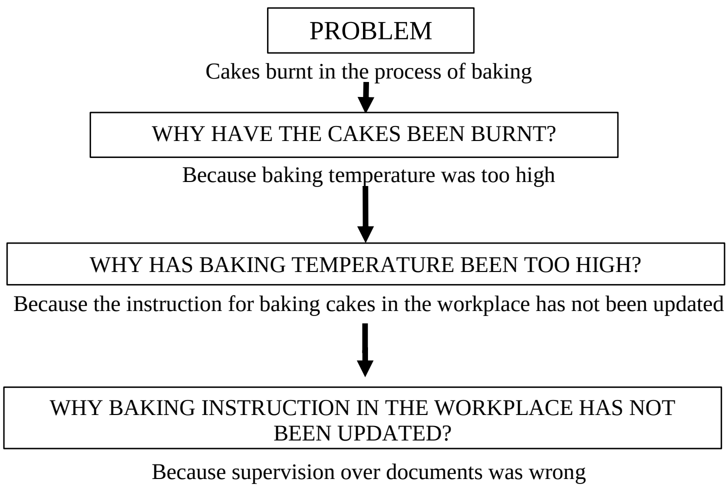

Fig. 3. The 5 WHYS principle [own work]

A simulation model in Arena software was drawn up in order to visualize the manufacturing system and continuous improvement of material flows (Fig. 4.). The model will be used for training employees and analysing problems appearing in the manufacturing processes as well as for evaluation of effects of implementing improvements and organizational changes.

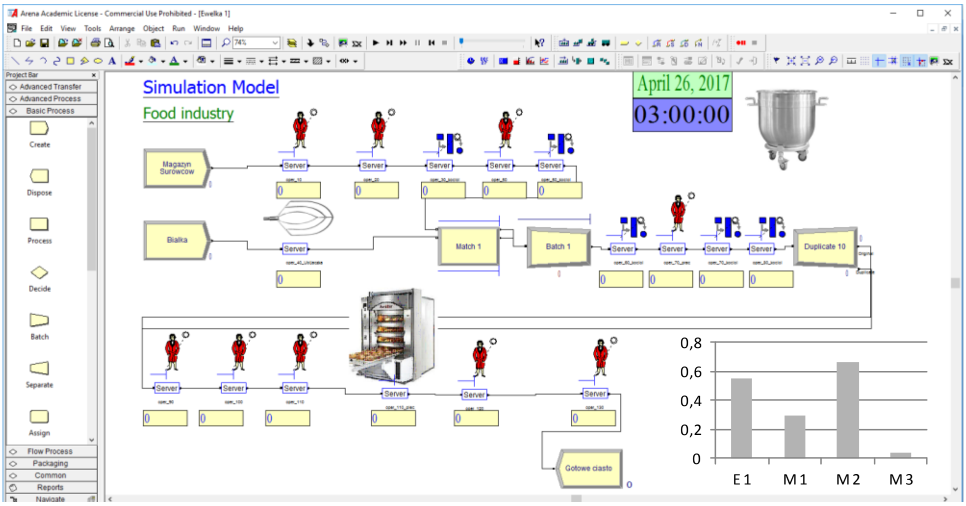

Fig. 4. A model of manufacturing system in the Arena programme [own work]

Performance of the system and load of individual manufacturing resources were defined as a result of carrying out a test simulation experiment.

3. SUMMARY

The best way for continuous improvement of production systems is involving all the employees of an enterprise in a continuous enhancement of the conditions and the methods of work. A programme of minor changes, introduced gradually, might cause a significant improvement of effectiveness of production in food industry.
Thanks to using modelling and simulation of production systems, it is possible to check different scenarios of solutions on a computer model. On the basis of the simulation experiment results, time of production orders realization has been estimated and exploitation of the available resources has been analyzed.

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Automotive industry, Automated guided vehicle, Intelligent logistic

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USAGE OF AUTOMATED GUIDED VEHICLE IN AUTOMOTIVE INDUSTRY

Abstract

Mass customization is fast growing in industry, especially in automotive industry. Car producers are facing challenges to react on this new conditions in all processes. Automated guided vehicles (AGV) as a part of intra-logistic system offers solutions for flexible and on-time feeding of production lines. This paper details of use of AGV in automotive industry as a key technology solution for intra-logistic.

1. INTRODUCTION

Modern manufacturing logistics like any other business functional area must by subject to the process of optimization and improvement in order to meet the requirements of market competition both in term of technological and customer satisfaction [1]. Enterprises are unable to adapt to rapidly changing market and to increasing demand requirement [2]. Based on this enterprises need to continuously look for some new innovation to be able to react on this customers' demands. In this area is automotive industry one of the most affected industry. Many of car modifications and customizations request correct and on-time supply. Delay or incorrect line feeding may cause fatal damages for car producers. Based on this are car producers are creating a concept of supply at such a level that these conditions do not occur. With the development of new technologies is also increasing requirements for software and hardware tools, which means enterprises need for constant innovation in this field. Companies operating in the automotive industry is currently pursuing initiatives to support the industry (eg Industrie 4.0, Smart Industry, Made different, etc.) and try to implement the principles of these initiatives. Examples are the basic principles of the concept of Industry 4.0 [3]:

- interoperability,
- virtualization,
- decentralization,
- real-time capability,
- service orientation,

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- modularity.

One of the technologies based on this concept and filling the highest quality requirements of the automated guided vehicle (AGV).

2. AUTOMATED GUIDED VEHICLES AS A KEY PART OF INTRA-LOGISTIC

Nowadays, mass customization faces to competitive pressures and market fluctuations. In the time of rapid changes in customer demand is necessary to flexibly react to customer requirements [4, 5]. Tomorrow's energy efficient manufacturing will require additional processing power at all levels of its infrastructure [6]. Since the introduction of ISO 14000 standard, it is recognized worldwide that sustainability is increasingly becoming an important business factor, organizations are now looking for methods and tools to help assess the fuller picture of the environmental impacts associated with their manufacturing and supply chain activities [7]. In this conditions is automated guided vehicle on of the key pillar of intelligent logistic concept [8, 9].

The Automated Guided Vehicle (AGV) is an automated guided cart that follows a guided path. This equipment is widely used in industrial fields and places of physical distribution. In general, an AGV is a driverless transport system used for horizontal movement of materials. The uses of AGVs can be divided into four main areas of application [10]:

- Supply and disposal at storage and production area
- Production-integrated application of AGV trucks as assembly platform
- Retrieval, especially in wholesale trade
- Supply and disposal in special areas, such as hospitals and offices.

AGV-Systems essentially consist of vehicles, peripheral and on-site components as well as the stationary control system (Fig. 1.).

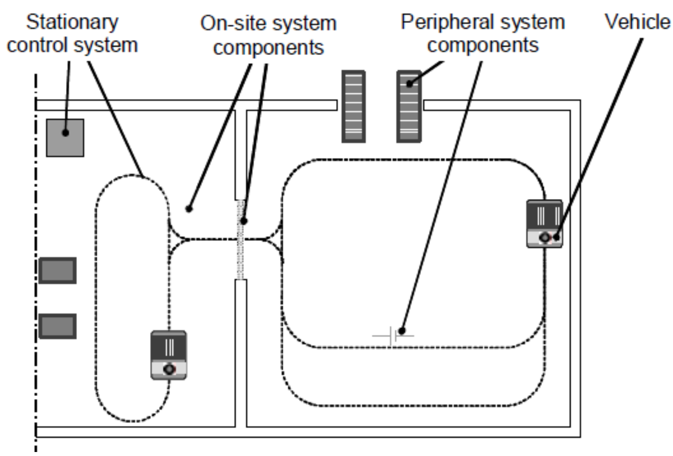

Fig. 1. Components of an Automated Guided Vehicle System [11]

Only the faultless interaction of all these components ensures efficiently working plants. Vehicles are the central elements of an AGVS as they perform the actual transportation tasks. The vehicles have to be designed individually according to the specific conditions of the environment. This concerns load handling equipment, the navigation system, the drive configuration and other aspects. The stationary control system covers all super ordinated control components. Its task is the administration of transportation orders, the optimization of schedules, the communication with other control systems via predefined interfaces etc. This system is also in charge of the customer interaction and often provides auxiliary functions such as graphical visualizations and statistical analyses. Peripheral system components represent the counterparts to various on-board equipment of the vehicles. Examples are battery loading stations and load transfer mechanisms. Aspects of the site's structural design that affect the AGVs as for example the ground, gates, lifts and so on belong to the category of on-site system components [11].

AGVs offer a flexible, dynamic approach to the required operation. In addition, elements including safety, accuracy, and increased productivity play a defining factor in establishing the role of the AGV as one of the staples in the development of a fully-automated material handling solution. Advantages of Automated Guided Vehicles can be defined in 4 areas [12]:

- Offers a Dynamic Design Solution - Anyone that has ever had the task of relocating a fixed conveyor system knows that this can be a cumbersome undertaking. Through the use of advanced AGV technology and wireless routing, vehicles can be quickly reprogrammed to change path or operation, eliminating the need for expensive retrofitting. New directions, tasks, and work cells can be created almost instantaneously without the need for physical equipment installation
- Modular System Elements - After the control system is in place, AGVs can be added as required by the growth of the operation. A fleet can start with a single robot then grow as demand increases, decreasing the initial investment and allowing for a gradual and seamless implementation. AGVs can be easily integrated with robotic attachments and existing or new material handling equipment to develop a fully automated system
- Safe and Predictable Technology - Through the advancement of control systems AGVs offer a safe and predictable method of delivery, while avoiding interference with human and building factors. AGVs can operate almost around the clock, without the need for breaks and vacation time. In addition, AGVs operate in conditions that may not be suitable for human operators, such as extreme temperatures and hazardous environments
- Increased Accuracy and Productivity - Automated Guided Vehicles, combined with RF technology, interface with the Warehouse Control System or Warehouse Management System to improve accuracy and efficiency. AGVs have little downtime, and operate at a fixed rate to meet a predictable metric for operational activity

3. CONCLUSION

Automated Guided Vehicles provide competitive advantage for companies in Automotive Industry. Implementation of this technology increase of company's productivity and flexibility. This key targets should be completed only with complex solutions related to all parts of logistic. If implementation of logistic concept is not realized as a complex, company will never reach goals defined on global markets.

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Production scheduling, Discrete optimization, Computer simulation

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PRODUCTION SCHEDULING USING THE COMPUTER SIMULATION

Abstract

The present paper deals with the interlinkage of production scheduling and computer simulation. The proposal of interlinking simulation and production scheduling issues brings many benefits to both areas. The aim is to outline and describe the structure of the proposed interlinkage of two industrial engineering areas and also to identify and reflect the benefits that these two areas can jointly offer to solve the problems in single-product.

1. INTRODUCTION

At present, the complexity of manufactured products is increasing in industrial companies, which results in increased requirements for production scheduling processes. Therefore, at present, it is necessary to develop solutions using digital business tools; that will greatly simplify and shorten the scheduling process itself, particularly one in single-product and small-series production. Currently, a very large number of methods, tools, and algorithms exist, however, they do not form a comprehensive system; they only solve partial production scheduling problems. For this reason, it is important to create a system that deliberately integrates partial tools into a functional platform; then the platform will provide for a complex solution in the production scheduling. The system will focus on sequential production scheduling due to the increasing complexity of products in discrete manufacturing.

2. COMPUTER SIMULATION AND PRODUCTION SCHEDULING

In production scheduling tasks, the main goal is to find a sequence of operations on available machines so that all the tasks can be processed as quickly as possible (this is considered the most common requirement) and/or one of the evaluation criteria can be maximized (for example, the total processing time of all tasks, total weighted task completion time, total weighted task delay). Individual operations can only come to the given machine once, because we consider the same number of operations and a set of defined machines. However,

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anecdotal evidence makes available situations when the processing of two consecutive operations on one machine is not considered limiting. If this is the case, we can separate two consecutive operations processed on the same machine by a fictitious operation with zero processing time. [1]

Dynamic simulation is an important tool used to support the planning, implementation, and subsequent operation of production systems[2]. In order to increase competitiveness, industrial companies have to constantly shorten the planning cycles for new products today. Important factors affecting today's production systems include [3]:

- the increasing complexity and variety of products,
- increasing quality requirements in terms of cost reduction,
- increasing demands on flexibility,
- shortening of the product lifecycle,
- reduction in production and transport size,
- increasing competitiveness.

Based on the findings with regard to solving production scheduling issues, it is important to use a computer simulation; through its application, we can achieve the results needed for the actual implementation of the solution into a real production system. We can use computer simulation in two ways [4]:

- The first option is to schedule the capacities by means of the production system and the management process, in which simulation can be used as part of the management system. Simulation can obtain instructions for production control directly or indirectly.
- The second option is to use simulation is to create emulation (imitation of the production system) for the basic process. This approach to solving the scheduling problem produces the manufacturing instructions, while the simulation model is used to represent the basic system and process. The simulation can be used to evaluate the performance of a particular approach to addressing the scheduling problem.

The intention of industrial companies is to create parametric simulation models for the scheduling in custom production, with scheduling problems being addressed by the proposed system, which will include a number of optimization methods for the discrete nature of production [5]. Simulation software will represent a real system that will evaluate different variants of the production instructions while providing instructions for production management.

2.1. Suggested interlinkage of computer simulation with production scheduling

After the initialization of the current technological procedures has taken place and the priorities have been set in the simulation model, the system will run a scheme for generating an implementable solution. In addition to the interlinkage of computer simulation and production scheduling, it is necessary to define what data will leave the simulation model and what data will then return to the model from the system in which an implementable solution is generated. The exchange of data will take place in a precisely defined form. Such a solution will be entered into the simulation software in which the schedule is evaluated. Evaluation criteria will be used to evaluate the generated solution.

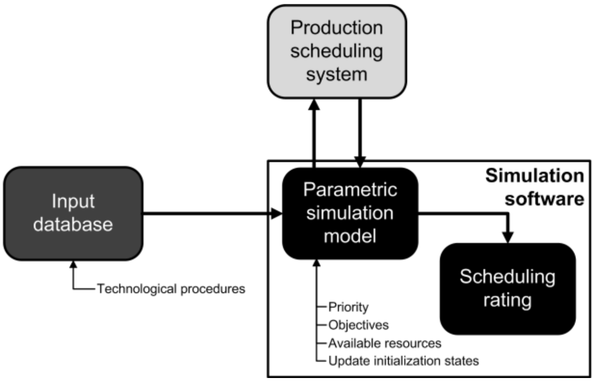

Fig. 1. Proposed interlinkage of computer simulation with production scheduling

The above figure (Fig. 1.) describes the procedure starting with input data processing and ending with outputs that provide a detailed overview of each task being performed.

2.2. Suggested interlinkage of computer simulation with production scheduling

For the valid state of the monitored production system, the data will be collected from ERP systems and databases. This information will then be stored in database systems (e.g.: Hadoop file system, Luster or QFS), which can also be placed on in cloud based data storage.

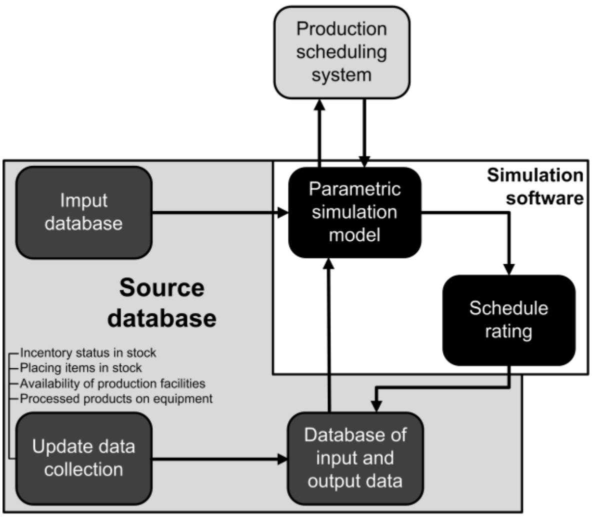

Fig. 2. Data collection for the proposed interlinkage of computer simulation and production scheduling

The above figure (Fig. 2.) shows the source database from which the information will be transferred into the parametric simulation model. In the source database, the information will be stored in a precisely defined form so that no imminent situations can occur in the simulation software when importing input data.

2.3. Suggested interlinkage of computer simulation with production scheduling

When designing the interlinkage of computer simulation and production scheduling problems, it was identified that the parametric simulation model will be used for:

- improving the solution (obtaining more accurate estimates),
- acquiring additional details about the sources (manufacturing operators, logistics),
- defining the states in which the production schedule update is initialized.

Possible limitations include:

- incomplete summary of details of the production system and processes,
- frequent changes in production facilities,- incomplete input information in the input database,
- unclear requirements for functions, role, and content of the simulation model being created.

3. CONCLUSION

Parametric simulation models have a huge potential for scheduling production because they allow for not only a simple user scheme but also for visualization and detection of problem situations in the production system. The proposed system will shorten the production scheduling process and will provide for interactive change of the timetable in accord with the circumstances. The benefits of the proposed link are, above all, the acquisition of more precise and more detailed activities carried out by individual sources. Weaknesses are the uncertainties arising from the creation of a parametric simulation model due to insufficient information on production processes and sources.

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Logistics, Integrated logistics, Management

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INTEGRATED LOGISTICS

Abstract

This article deals with basic information about individual form of logistics trend called integrated logistics. The core of the article contain description of integrated logistics, the development of integrated logistics management in company and the benefits that brings to company. The article presents the usability of new knowledge in the next direction of research in the area of an interactive logistics planning system based on virtual reality technologies.

1. LOGISTICS

Nowadays gives us a view of the logistics system in his full lifecycle. From the first idea about his creation, through construction, completion and continuous improvement. As we can follow the product lifecycles, it is necessary to pursue the development of logistics systems using the latest technologies and computer applications [1]. Customers are getting more and more demanding, they will be satisfied if they do not have wait on the ordered product or service too much long, they will not have to make every effort to obtain it, the product must correspond with the requirements regarding the quality and quantity and customers pay a fair price for products or services. Solving problems is based on an examination of logistics chain, in the identification of redundant or inefficient articles, and finding some solutions that enables reduction in production lead time, improved customer services, and that will make the entire chain more flexible and economical [2]. One of these solutions is integrated logistics system.

2. INTEGRATED LOGISTICS

Logistics integrates all activities of internal and external company into one activity or process, leading to more effective customer service at the lowest possible total cost. Integrated logistics presents management (forecasting, planning, organizing, operational management, control) of information and financial flows related to life cycle of product, from product development to delivery, production and distribution to final consumers to maximize customer satisfaction at the lowest cost. The ultimate effect is to increase productivity. Implementation of integrated

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logistics system into company is not easy it may takes several years. Logistics created during making of concept of an integrated logistics, need a support. This kind of support have an acronym ILS (Integrated Logistics Support), which requires an administrator who will be on "interface" between many logistics elements (Fig. 1.).

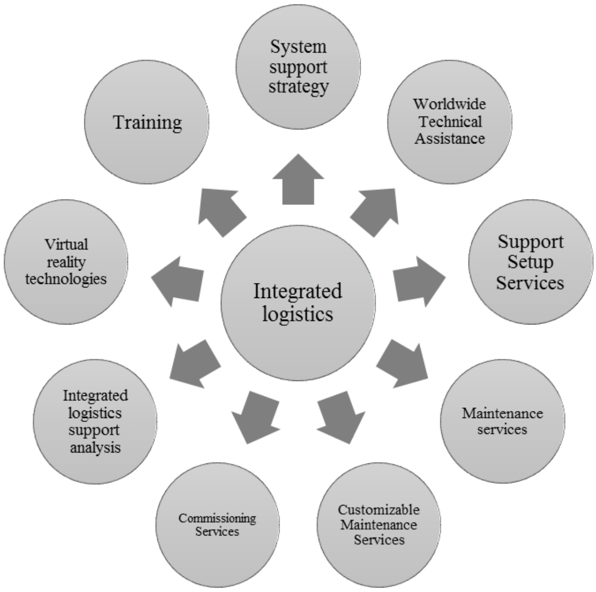

Fig. 1. Integrated Logistics Support

Integrated logistics is in many literatures defined also as "the process of prediction of customer needs", where the interests of company leads to raising capital, high-quality raw materials, plenty of experienced people, using of latest technologies and precise information are necessary to fulfill the needs and wishes, requirements of customers. The management of integrated logistics chain is called the integrated logistics management.

2.1 Development of integrated logistics

Many variables have an impact on the evaluation and development of integrated logistics in company. The first major milestone was growth in the awareness of consumers themselves. Product lines had expanded to satisfy the growing demand.
The second factor was introduction of experts to the development of information technologies and to the actual sphere of logistics management, which quickly found claim in computer applications and on the Internet. This application reach greater efficiency in transportation, scheduling, inventory management, warehouse designing, etc.
The third milestone in the development of integrated logistics is global economy. Rising interest rates, increased competition and distribution costs meant that many companies reoriented their attention on reducing or increasing prices, many companies have been forced to rethink modes of transport. Another need was minimum level of inventory, because they create additional costs. The fourth milestone is a growth of business and development of world trade.

Integrated logistics and supply chain management provides a framework in which falls the network structure, business processes and components for information managing. It plays a major role during determining key elements and mechanisms that support logistics platform and systematic integration. Between this key factors of the logistics system is possible include shippers, suppliers, carriers, warehouse, warehouse providers, terminal operators, government (regulator of logistics).
To support of development of integrated logistics in company, it is necessary to pay attention to important tools on identification system reliability and reasons of possible problems. Integrated logistics system can have strong relationship with the security system, because using common sources of data can lead to loss of data or inaccurate information, so that is important to detect errors in system, errors caused by human, predictions or system reliability [3].

2.2. Development of integrated logistics management in company

Integrated logistics management is characterized as a technique that uses various sources to satisfy the demand of customers in time. Activities related to integrated logistics management: business logistics, logistics engineering, physical distribution, inventory management, supply chain management, etc. The effectiveness of an integrated logistics system requires from a strong involvement of management, in detail prepared an integrated logistics system, management team and close coordination between its members. Many developing companies start to create systems and software, which offer other companies for creation a reliable integrated logistics management system. Objectives of integrated logistics management should be: rapid response, minimum variance, minimum inventory, movement consolidation, etc.

2.3. The advantages of using integrated logistics

Integrated logistics is composed from many support elements, which are integrated into the life cycle of system and is checked at regular intervals. This whole is understood as a whole, which is greater than the sum of all its parts. In other words, combination of all support elements leads to highly efficient processes that strongly increases the productivity, for example, of manufacturing, or customer service systems. It is possible to define benefits:

- Improved customer service:
  - clear information about products and stocks,
  - reliable service levels,
  - shorter delivery times.
- Cost savings:
  - more efficient use of logistical resources,
  - more effective use of company resources.
- Optimization of logistics networks:
  - optimal product flow,
  - simplified administration of documentation.
- The standardization of global logistics processes:
  - the periodic inspection of the supply chain,
  - correct using of information technology systems,
  - integration between information technologies,
  - finding better way how to wrong submit a report about logistic chain, etc.
- Possibility of using a virtual reality tools for improving logistics [4]:
  - computer simulation,

- training of operators with using virtual reality,
- improving picking of goods in warehouses,
- using a software to test a new solutions for improving integrated logistics, etc.

3. CONCLUSION

Over the years the development of information technology has been shown, that an integrated logistics system is increasingly important mainly for distribution-oriented companies that are exposed to high domestic and global competition. Survival of distribution, logistics and manufacturing companies has become a fundamental problem mainly because of high competitive fight [5]. Framework of an integrated logistics system described in this article includes information about the system, relationships and its operating philosophy. An inevitable trend and development in the future will be more intensive by using of new information or virtual reality technologies, which is necessary to increase productivity in logistics, "the distribution" of industry. Using the potential of integrated logistics is one of the steps to a successful logistics company.

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Intervertebral disk, Load of woman, Manipulation with load, Working posture

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LOAD OF INTERVERTEBRAL DISK L4/L5 IN DEPENDENCE OF WORK FACTORS

Abstract

The article contains information about the values of female worked load due to different working postures associated with manual handling of loads with different weights. It also processes information about values of the intervertebral disk L4 / L5 load, which is the most burdened during manual handling. It provides information about development of the intervertebral discs L4/L5 load at different torso angles for different load weights.

1. INTRODUCTION

The activities of workers at logistics and maintenance include many physically demanding and diverse activities associated with manual handling of loads. A high number of industry workers suffer from back, upper or lower limbs pain. The reason is that they make excessive manual handling of loads. The result from this load is often increased due to additional factors such as non-physiological working postures, static load, vibration, personality characteristics of the operator and others. [1]

2. EVALUATION LOAD OF OPERATOR DURING MANUAL HANDLING

At present, material handling is the only part of physical load assessment at logistics. However, in context of assessment the load of operators during manual handling is there only one way used at industry companies where is calculate the maximum weight manipulation limits and the total manipulated weight mentioned in the legislation of Slovak Republic. [2,3]
At this part of article, it is possible to find other ways of assessment the operator's load in manual handling of load, from which we obtain information about the degree of risk arising from the work activities.

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2.1. Ergonomic analysis for evaluating operator load rate

In the context of the workload assessment for women workers and assessment the risk of occupational health diseases, was used ergonomic analysis OWAS (The Ovako Working Posture Analysis System). There were analysed eight working postures of female operator not connection with manual handling with load. And also, operator load in the same working positions when they handling with 5 kg, 10 kg and 15 kg weight of load. These loads were selected on the basis of the limits defined at the Slovak legislation for female workers. The evaluation was made in the software Tecnomatix Jack for women of average height and weight. [3]

Tab. 1. Results from OWAS analysis for different working postures

	OWAS							
	Squat	Deep bend	Maximum stretched of upper limbs	Angle in elbow 90°	Sit	Lateral rotation	Axial rotation	Upright stand
Weight of the load								
0 kg	3	2	1	1	1	2	1	1
5 kg	3	2	1	1	1	2	1	1
10 kg	3	2	1	1	1	2	1	1
15 kg	3	2	1	1	1	2	1	1

From the results of ergonomic analysis OWAS (Tab. 1.), it can be seen that the highest risk of health diseases due to the non-physiological working position is in case of squat. Then in the case of deep bend and lateral rotation there is an increased risk of health damage. Other analysed working positions only from the point of view the working position do not represent a risk of harm to health

2.2. Load of intervertebral disk L4/L5 during manual handling

The load on the operator due to the working positions associated with the manual handling of the load can be analysed by several factors directly affecting the operator. One of them is also the force that is expended on the L4 / L5 segment.

At this caption is described the dependence of the intervertebral disk L4 / L5 load from the working position type (Tab. 2.) during which is the manual handling operation performed when the weight of the hand-manipulated loads is changed.

According to the NIOSH methodology, the allowable force value for the L5 / S1 segment is 3 400 N for long-term load. The maximum permissible load shall not exceed limit of 6 300 N.

In the case of the intervertebral disk load analysing due to the increasing weight of the manual handling of load for eight selected work postures (Tab. 2.) wasn´t detected excessive load compare with limits at NIOSH methodology.

Tab. 2. Results from LBA analysis for different working postures

	Load of intervertebral disk [N]							
	Squat	Deep bend	Maximum stretched of upper limbs	Angle in elbow 90°	Sit	Lateral rotation	Axial rotation	Upright stand
0 kg	1315	1378	530	333	341	624	305	310
5 kg	1943	1803	1023	590	608	627	355	359
10 kg	2572	2231	1548	850	875	643	453	419
15 kg	3204	2645	2080	1109	1141	658	523	481

We can also conclude that in case of the working position squat, the deep bend of trunk, maximum stretched of upper limbs during manual handling of 10 and 15kg load, were value of load higher compare with others.

3. DEVELOPMENT OF LOAD DURING DIFFERENT BENDING FORWARD OF TRUNK

At this part of article is evolution the development and changes of load L4 / L5 depending on the size of the spine deflection from the neutral body position for the female worker with the simultaneous change of anthropometric characteristics, which in this case was the weight and height.

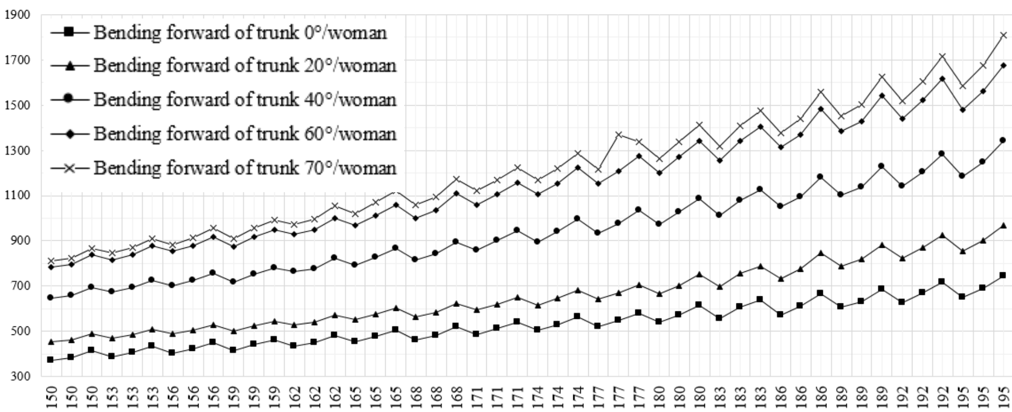

Fig. 1. Dependence of intervertebral disc L4 / L5 load from anthropometric characteristics of woman operator and the bending forward of trunk

The smallest height was selected on the basis of the smallest height of women at anthropometric atlas in TC Jack. The highest height was selected on the basis of the highest man at anthropometric atlas in TC Jack. For each height in the range from 150-195 cm with the spacing values 3 cm was analyzed for intervertebral disc 3 weight variants. Underweight, Ideal weight and slightly overweight. To determine the size of the intervertebral disc L4 / L5 load with given parameters was used ergonomic analysis LBA (Lower Back Analysis in Digital factory TC Jack.

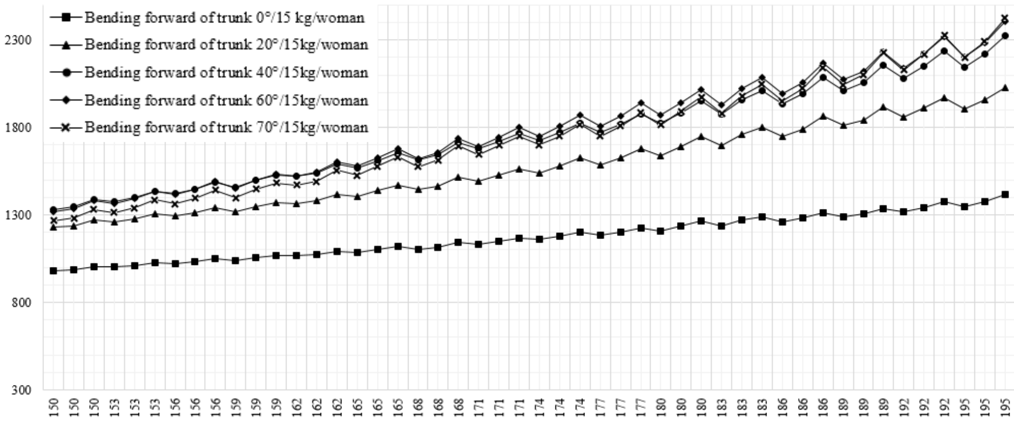

Fig. 2. Dependence of intervertebral disc L4 / L5 load from anthropometric characteristics of woman operator and the bending forward of trunk during manipulation with 15 kg load

From collecting data about the behaviour of the intervertebral disk L4 / L5 load it can be concluding that with comparing the pressure on this segment the pressure is significantly higher in the same working position in cases when this position is also influenced by manual handling of the load. With greater weight of the manipulated load and the greater angel of bend forward of trunk, the pressure on the intervertebral segment is also increased directly proportional.

4. CONCLUSION

It can be appreciated that when we compare the Slovak legislation with used ergonomic analysis was not found contradictory findings about lord of the woman operator during manual handling of the load.

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Simio simulation software, Health care systems, Agent based simulation

Ladislav KRKOŠKA*, Milan GREGOR**

CONCEPT OF THE AGENT BASED SIMULATION FRAMEWORK FOR SIMULATING HEALTHCARE FACILITIES

Abstract

Article discusses about the concept of simulation framework for use of simulating the detailed activities of medical facilities using the agent approach. The study SHFAOF (Simulating Healthcare Facilities by Agent Oriented Framework) will to be help in developing detailed and easily customizable simulation models of healthcare facilities. One of the reasons for creating such a specialized framework is the presence of healthcare standards and experiences with previously used discrete event simulation in healthcare facilities. The article describes the concept of SHFAOF, application layers, objects and future planned development.

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, 2]. By creating the convenient environment and objects, can be dramatically reduced the time for not only creation of ABS itself, but 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.

1.1. Theoretical assumptions for modelling

Genesereth a Nilsson introduced formal models of several types of intelligent agents. Intelligent agents may be defined in the form of 8-gon, four datasets / data sources: (D, S, T, A) and four actions / abilities of the agent: perceive, infer, select and act, where [3]:

- D is assigned a portion of the predicate database for the agent,

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- S is the set of possible external states of environment,
- T is the set of possible assignments of S (interpretation of S by agent),
- A is a set of possible actions.

If we include the elements of the formal model in accordance with the functional intelligence elements of the intelligent agent, it can be shown that these are two equivalent definitions and that the formal model is in fact a general description of its function. Functional interpretation of intelligent agent in confrontation with formal models of its functions is in Fig. 1.

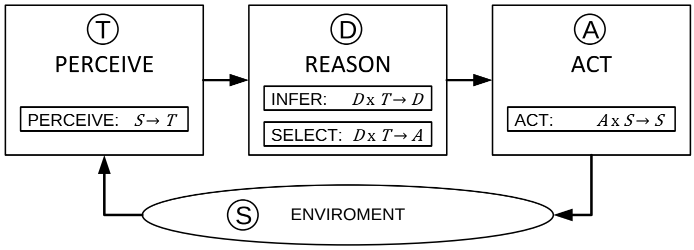

Fig. 1. The functional interpretation of the intelligent agent [4]

1.2. Theoretical assumptions for platform selection

The most recent study includes an overview of 24 different platforms for agent design. Described were Pure-agent platforms, Agent application frameworks and Agent-based simulators, because each of them is capable to be the agent platform. Comparison of this work was inspired by the methodology set [5]. Listed are three representatives each of the categories platforms. Condensed comparison of selected MAS developing platforms is in the Tab. 1.

Tab. 1. Comparison of selected MAS developing platforms

	MAS platform	Several selected evaluation criteria			
		Licence, Licencing	Scala-bility	Standards support	Programing languages
Pure-agent platforms	Agent F.	LGPL	good	FIPA	Java, AFAPL
	Cougaar	Cougaar OS	high	-	Java
	JAS	LGPL	average	FIPA, Gr. ML, XML	Java
Agent application FW	JADE	Lgplv2	high	FIPA, CORBA	Java
	Jadex	Lgplv2	high	FIPA, SOA, WSDL	Java, XML
	JIAC	AL V2	high	-	Java, XML
Agent-based simulators	Anylogic	OS	high	GIS, 3D	Java, UML-RT
	Madkit	GPL	good	UML	Java, C++, Python
	Simio	Wide	high	OO model, GIS, CAD	50 .NET, viz. prog.

2. THE CONCEPT OF 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 project 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 concept SHFAOF, which should be realized in the Simio.

2.1. Concept of SHFAOF levels and structure

Whole SHFAOF concept is based on the fact, that in healthcare facilities are such a number of specifics, that universaly or industrially oriented simulation software do not allow for ease and natural simulation of real healthcare facilities operative. There is also a fact, that medical activities are described in the form of healthcare procedures standards. However the main idea is that once all the standards will be processed, the analyst will have to deal with only specification for concrete healthcare facility. The composition of the SHFAOF is in Fig. 2.

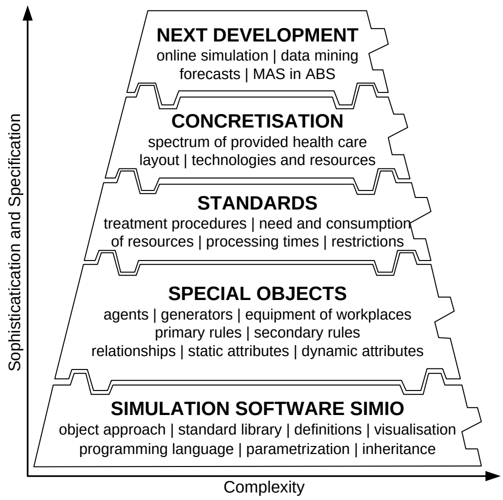

Fig. 2. Composition of layers and development of the SHFAOF study

As Simio simulation software evolves continuously, we can complement the individual layers of this concept. Building block of concept is therefore simulation software Simio, allowing their tools and environment implements our ideas. In Simio simulation software, special objects will be created to the form of a special dedicated library. Special Objects will include decision-making rules and environment management co-operation mechanisms. Layer of the standards will be the highest asset for the analyst. This will include healthcare procedures, material needs, and so on. The last layer of the study is a direct application, where will be verified benefit of a solution for the process of modelling a particular healthcare facility. That will be also work of analyst in future use.

2.2. Concept of general SHFAOF object

Decisions in the system will be acquired through communication and negotiation between objects. We plan, that the task originated in the system, should be automatically sub-classed and processed by objects based on the community's decision or based on the decision of the agent itself. In order for the object to be able to make its own decisions, it must meet the basic aspects of IO as describes Fig. 3.

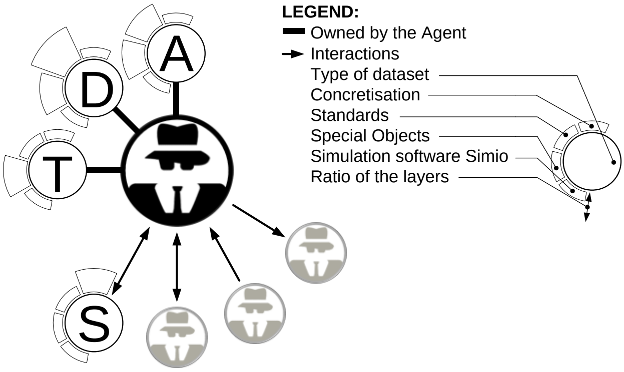

Fig. 3. The concept of SHFAOF's agent in interaction with environs

The SHFAOF's agent is the highest grade among the objects of the add-on simulation framework. It will operate amongst other agents and the environment. Using the SHFAOF, environment will be only the largest part of analyst work in the model. Agent's datasets have different shares in the developmental stages of the study, but also according to the agent's specificity. The greatest challenge will be to process a high proportion of standards layer.

3. CONCLUSION

Currently, we detailing the structure of add-on framework and testing different models of interaction between objects. However, the framework still needs a lot of work. In particular, it is necessary to point out that an unlimited version of Simio simulation software is required for the design and simulation of such complex objects. We hope that with our study we touch Simio LLC and they will provide us with the development version, which supports unlimited step design of objects.

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Health care systems, Adaptive logistics, Agent based modelling and simulation

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THE EFFECT OF AGV REAL POWER CONSUMPTION ON DECISION-MAKING IN LOGISTICS

Abstract

The present paper discusses the usage and maximum utilization of AGVs, simulated in Simio simulation software, in healthcare facilities. Nowadays, every sophisticated system element can provide numerous data, also called Big Data. However, the essential step is to correctly select and generate factual information. The paper deals in detail with the issue of AGV power consumption and with how communication between the AGV and the data on the power intensity of different operations can be used to estimate consumption. This makes it possible to optimally utilize the energy in the AGV batteries or decide on the dilemma of exceeding the level of the battery formatting residual power at expense of the exponential extension of the time needed to recharge the battery.

1. INTRODUCTION

The tools and architecture of the current simulation software makes it increasingly possible to mimic even more complicated and complex processes [1]. More physical aspects can be included in the process simulation and thus allow the actual values of the phenomena to be calculated exactly as they arise in real systems.

Our aim is to create a framework in the Simio simulation software, consisting of different types of agents and objects forming a kind of a library of intelligent objects. This library is intended to simplify the creation of complex and detailed simulation models of healthcare facilities. Among the objects of this intelligent object library is the underpass AGV. In previous publications, we described the basics of its interaction with the environment, as well as the reworking of space management and the identification of obstacles. Healthcare facilities are specific cases of application and use of AGV. There are many limitations and obstacles to be considered, foreseen, and embedded in the final decisions on planning the most appropriate supply routes [2].

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2. AGV POWER CONSUMPTION AND AVAILABILITY

The present paper deals with the issue of AGV power consumption in its complexity; it also tackles the estimation of the future consumption not through the mean values gained over the recent period, but rather through the decomposition of the planned route into individual operations that can be assigned specific power consumption. Through MPC (Model Predictive Control), it is possible to robustly estimate the final residue in the AGV battery after performing a planned logistics order.

2.1. Factors influencing AGV power consumption

The AGV power consumption level varies depending on different parameters. In the agent simulation, these parameters can be called attributes. Thus, the AGV attributes will also include those ones that will be used to determine the current power consumption; that is to say, over time it dynamically changes one of its attributes – the battery residual power. The factors affecting the level of AGV power consumption are described in Fig. 1.

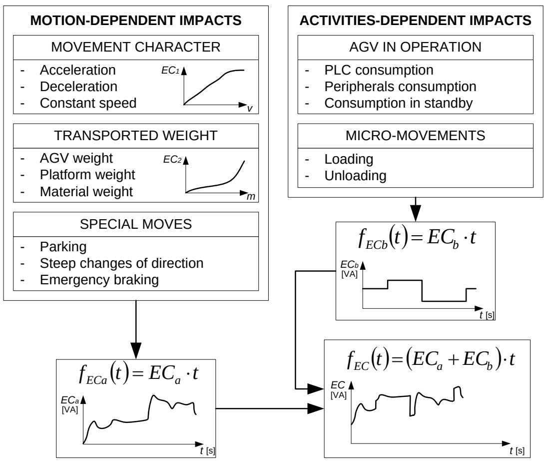

Fig. 1. Factors affecting AGV power consumption

The basis of conveying what factors influence the AGV power consumption lies in describing their interdependences and their impact on the final function that expresses the AGV power consumption valid at time *t*. Therefore, this is the case of the decomposition of the planned AGV route into individual steps for the execution of which the amount of power equaling the area between the $f_{ec}(t)$ and the time axis at the intervals $<t_0; t_1>$ is required. This can be exemplified by AGV accelerating from the state of inaction (when power consumption is determined by means of a familiar function), the weight of the AGV itself and the empty platform (we determine based on the familiar look up table) the PLC and sensory peripherals of which are, naturally, triggered during the acceleration to the final speed value.

$EC_{1,2,\dots n}$ – partial power consumption, given by constant or functional dependence (equivalent P = dW/dt) [VA]
EC_a – total power consumption of AGV traction engines [VA]
EC_b – total power consumption of controller PLC and other AGV actuators [VA]
EC – overall current AGV power consumption [VA]

2.2 Factors influencing the AGV power availability

The availability of AGV power is not affected by its mere power consumption, but also by the gradual reduction of battery capacity, by the conditions in which the battery operates, and, last but not least, by the way the battery cells are charged, as shown in Fig. 2. In particular, it is a matter of what battery type is used; in general, however, it can be claimed that if the residual power in the battery reaches less than 20% of its maximum capacity, exponentially, the time needed for its being fully charged extends. This is due to the charging cycle, when it is necessary to format the battery with a low current first.

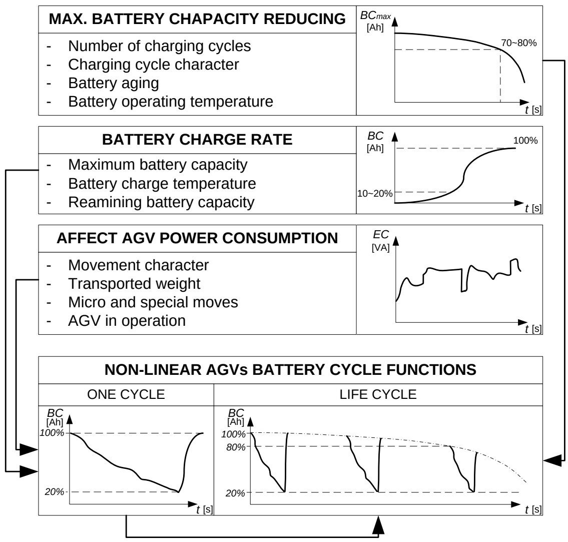

Fig. 2. Factors influencing the AGV power availability

The gradient of power consumption and the battery charge speed rate affect one battery cycle. In the long run, however, they are equally involved in the battery overall life cycle, whereby its maximum capacity is gradually reduced, and consequently only a limited number of operations can be performed on a single charge.

2.3. Using AGV power consumption estimate for logistics decisions

It is necessary to be aware of the factors influencing the battery life cycle not only to be able to simulate the current state but also to determine the amount of power needed to perform the planned performance when deciding how to perform it (Fig. 3.). The amount of power left after a partial logistics operation is determined by the following formula:

$$BC_n = BC_{n-1} - \left[\int_{t_0}^{t_1} f_{EC}(t)dt \right] \cdot c_{EC_K} \tag{1}$$

BC – current remaining battery power, given for nominal voltage (equivalent Q = 3600C) [Ah]
BC_{max} – maximum possible battery power, functionally changing based on working conditions [Ah]
c_{ECK} – power consumption adjustment factor based on previous knowledge of over-consumption in the system

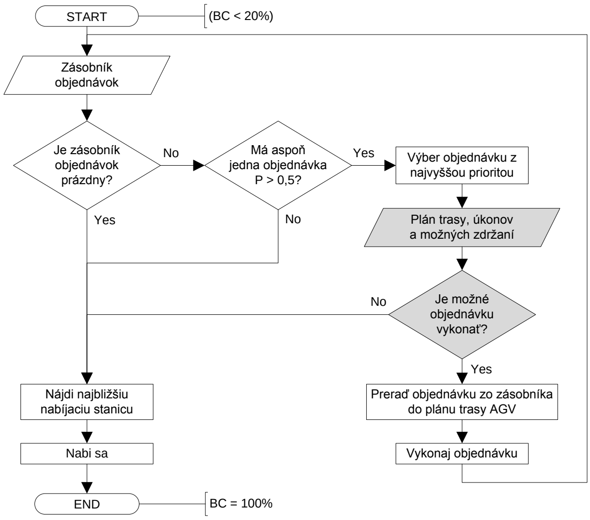

Fig. 3. Using the AGV power consumption estimate when deciding about AGV charging

By retrieving the data into the schedule of the route plan, by taking the necessary actions, and by counting possible delays in the system, the AGV will determine whether or not it is possible to execute the order and move it from the endpoint to the nearest charging station, with the remaining battery power.

3. CONCLUSION

At present, the system operates in the Proof of Concept mode by specifying the functional relationships between variables and functions influencing the trends in power consumption and in recharging. In the future, we plan to supplement and refine this concept with real-life AGV data, with a specific battery type, with peripherals, maintenance, and others [3]. This functionality will be part of the AGV object representing one of the objects of an internal logistics system. This will eventually be part of Simio's simulation framework.

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Reconfigurable manufacturing systems, Multi-agent systems, Modular systems

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NEW APPROACH TO MANUFACTURING SYSTEMS IN FACTORY OF FUTURE

Abstract

The new requirements in production require new approaches for designing production systems. Dynamically changing market demands drives future production systems to be able to quickly adapt to the production of new products. Reconfigurable manufacturing systems that are able to quickly change the layout of production modules and quickly adapt to the production of the new product meets these requirements.

1. INTRODUCTION

In the last few decades, new production requirements have arisen and new requirements have not been met by traditional production systems. Production systems have begun to require the ability to respond to changing customer requirements and hence the need to produce customizable products at the lowest cost and high quality in such a way that companies can maintain their competitiveness.
These customer requirements have been transformed into the required features of the new generation Factory of Future [1] manufacturing systems, namely: real-time production system responsiveness, fault tolerance, system flexibility and scalability (adding, removing and increasing system performance) Decision-making decentralization, decision-making and planning, modularity (plug & produce), flexibility, agility, or simplification of control software.

2. DESCRIPTION OF TECHNOLOGIES AND SYSTEMS

Due to the modularity and reconfigurability requirements, multi-agent system management has been selected. The production system consists of production cells that are easily replaceable and can be moved according to the product requirements. Such a system is able to dynamically respond to production requirements and quickly adapt to the new product type.

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2.1. Software agent

A software agent is an active representative of a user, a designer, a programmer who seeks to achieve goals predefined by his agents. The agent is autonomous and therefore is able to independently decide without user's intervention.

2.2. Multi-agent systems (MAS)

A multi-agent system is made up of several agents who, through communication, cooperation, coordination, and negotiation, seek to achieve local or global (common) goals. In this proposed system, we distinguish three main types of agents:

- Intelligent product agent (IPA)
- Mobile platform agent (MPA)
- Mobile robotic system agent (MRSA)

2.3. Reconfigurable Manufacturing Systems

Reconfigurable manufacturing systems (RMS) represent an innovative production method. RMS represents an adaptive system able to adjust its production capacity due to fluctuations in demand for products and adapt its functions to the new products. RMS is designed to quickly change the structure, hardware, and software components within the selected product family. Such manufacturing systems are designed as modular, using reconfigurable manufacturing machines and devices. They often work on a plug and produce basis, which allows very fast integration and use of the latest technologies. [3]

3. SYSTEM LAYERS

The proposed solution is divided into three layers that are mutually interconnected and communicate with one another (Fig. 2.).

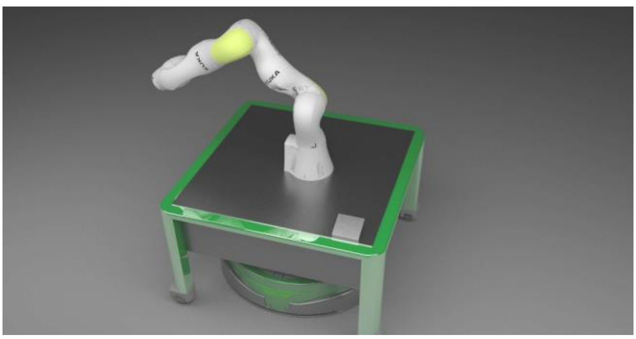

Fig. 1. Modular platform with superstructure

3.1. Layout Manager Layer

The layout manager's task is to build a new production line layout based on Intelligent Product Agent requirements. According to the required operations, Layout Manager chooses appropriate modular platforms that are able to provide the necessary operations at the lowest price. The price is determined by the sum of the distance factor of the platform from the new position, the cost of production factor and the processing quality factor. Subsequently, a pheromone-based allocation of mobile platform agents by Layout Manager occurs.

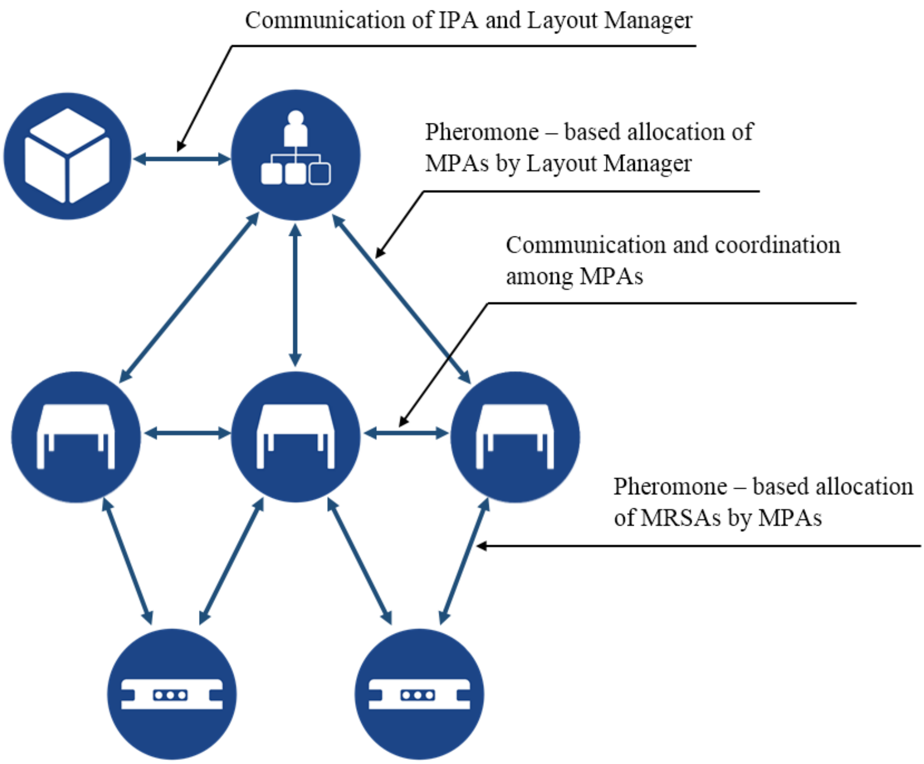

Fig. 2. System layers of proposed reconfigurable manufacturing system

3.2. Communication and Control Platform Layer

At this level there is communication between the different platforms in the production process. Modular platforms carry superstructures (Fig. 1.) that provide manufacturing, assembly or logistics services for intelligent products. Communication between modular platforms is necessary for the smooth transition of intelligent products to manufacturing islands. Manufacturing superstructures provide processing services, assembly superstructure allows components to be added to the intelligent product, and logistics superstructures allow smooth product flow between production and assembly superstructures.

3.3. Communication and Control Mobile Robotic System Layer

Upon the arrival of the requirement to reconfigure the manufacturing system, mobile robotics agents are allocated by mobile platform agents. Mobile robotic system moves from its initial position to the current position of the modular platform on the path designated by Layout Manager, grabs it and moves to the desired location. In case an obstacle that is not part of the system appears during transport, it handles information about this obstacle to Layout Manager and waits for a new path to be specified.

4. ADVANTAGES OVER EXISTING SOLUTIONS

This solution significantly reduces production ramp up time. Compared to traditional production systems, time from product demand to production is shorter. This allows a more rapid response to volatile demand when it is easy to expand production capacities. The expansion of production capacities is limited by the available vacant space in the production hall. It is also possible to react more quickly to an eventual failure, when it is possible to replace individual production cells by replacing the entire modular platform.

5. CONCLUSION

Reconfigurable manufacturing systems that are able to quickly adapt to changes in production demands are the future of manufacturing systems. The modularity of the system makes it easy to change the layout of the production line and to change the material flow. The system is able to quickly respond to possible malfunctions and thus maintain continuity of production

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Productivity, Management cycle, Efficiency, Effectiveness

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AN APPROACH TO PRODUCTIVITY APPRAISAL IN THE ENTERPRISE

Abstract

The productivity measurement is the quantification of both the output and input resources of a production system. Productivity is key to maintaining competitiveness, at both the organization and country levels, and in ensuring sustainable socioeconomic development. The various productivity-enhancing tools, techniques, methods, and practices that have been developed and adopted over the years in the production and consumption of goods and services are essential to the dynamism of economies.

1. DEFINITION OF PRODUCTIVITY

The concept of productivity has evolved over the years to represent more than an efficiency ratio. From cost and quality issues, its scope has expanded to embrace social concerns - such as job creation, job security, poverty alleviation, resource conservation, social responsibility - to business excellence, governance, and environmental protection (referred to as Green Productivity). Today, other productivity concepts that have evolved include social productivity and knowledge productivity. There are several ways of understanding productivity, but there are at least two essential definitions often used and espoused.

Productivity (1) is the relationship between the quantity of output (goods and services produced) and the quantity of input (i.e., resources such as labor, materials, machinery, and energy) that are used in production [1].

$$\text{Productivity} = \text{Output}/\text{Input} \tag{1}$$

Productivity is concerned with how efficiently goods and services are produced and the value created by the production process. If a product is made at the lowest cost with high quality and can be sold competitively in the market at a price higher than its cost of production, then its productivity level is considered high. [2, 3] The objective of productivity (2) is to maximize output and minimize input.

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$$\text{Productivity} = \text{Efficiency} + \text{Effectiveness} \qquad (2)$$

The other element of the productivity equation is effectiveness. [4, 5] This relates to the attainment of the desired goals or outcomes set by the producer of a product or service. If the customers are highly satisfied in using the product or service, this could mean higher revenues and repeat orders for the product or service. It could also mean higher return on investments for investors and even a better image or reputation for the company or organization.

1.1. Impact of productivity in the enterprise

Productivity is an integrated concept, a combination of principles from various disciplines such as science, engineering, economics, finance, and psychology. Productivity improvements or enhancements are generally achieved through collaborative efforts that target specific issues affecting an organization. In short, achieving improved productivity involves a managed and systematic process; it does not happen by coincidence or accident. Improvements may be planned once at the end of a staged process, incrementally from step-wise initiatives, or in spurts through breakthroughs or innovations.

The Productivity Management Framework in Fig. 1. is a good way of illustrating the cycle of managing productivity in the enterprise.

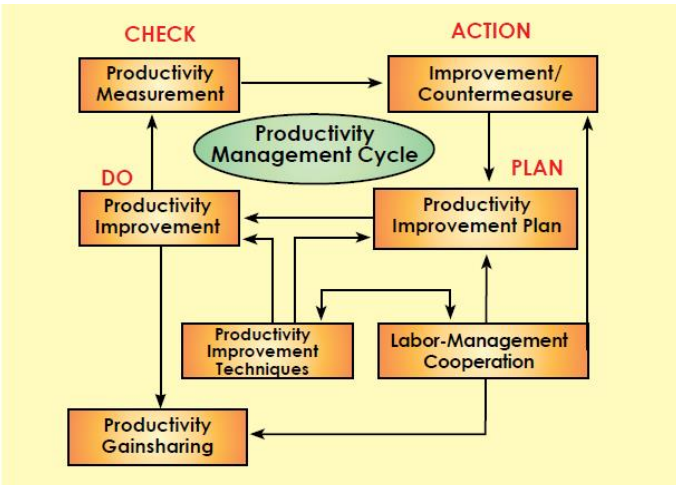

Fig. 1. Productivity Management Framework

The framework starts with CHECK, assessing the organization's present condition or productivity level. After checking or assessing, the next step is ACTION. At this stage, the organization looks for countermeasures to remedy the problem or improve the present condition. The next step is PLAN, wherein the organization will determine what productivity improvement program or project it will implement. The final step is DO, when an organization starts to implement the planned productivity initiative or intervention. If the implemented program results in an increase in productivity level, the management may opt to share the gains of improvement through productivity gainsharing. After implementing any productivity improvement activity or intervention, the organization will again CHECK on the status of improvement. The cycle continues.

1.2. Productivity initiatives

In this article, the productivity-improving or enhancing initiatives, which can be in the form of a basic principle, tool, technique, method, practice, guideline, model, or approach that had been espoused in the past years, are presented in a simplified framework to allow users a quick grasp of how they are used and how they fit into the larger picture of an organization's productivity goals. They may be grouped into the following four Ps, which represent areas of concern in any organization that is aspiring to achieve productivity improvements - people, product, policy, and process.

1. **People-focused:** When a productivity-enhancing initiative aims to directly raise the efficiency and effectiveness of a worker.
2. **Product-focused**: When a productivity-enhancing initiative aims to improve the quality and responsiveness of a product to consumer demand.
3. **Process-focused:** When a productivity-enhancing initiative aims to make the planning, design, production, and delivery of goods and services more efficient and effective.
4. **Policy-focused:** When a productivity-enhancing initiative aims to improve the overall environment for production and/or consumption of goods and services.

In many cases, the productivity initiatives can be designed and implemented with multiple goals, and are, therefore, cross-cutting in their applicability and impact. Fig. 2. shows the productivity improvement framework used in companies, which follow these four Ps.

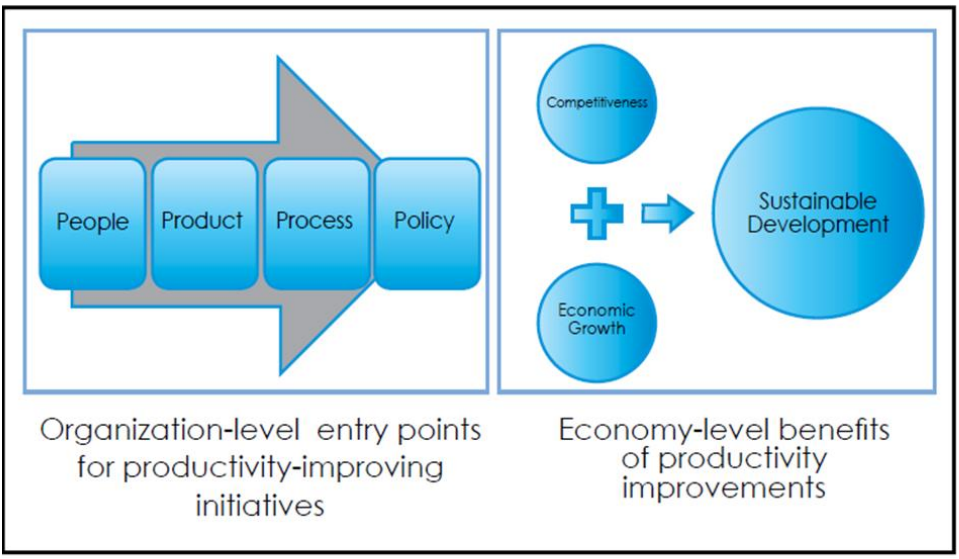

Fig. 2. Productivity Improvement Framework

2. CONCLUSION

The productivity measurement has always been an important aspect in manufacturing companies. Nowadays, the issue of productivity improvement, especially in developing countries, has become important for manufacturing firms' managers, strategic planners, government policy makers and it is becoming a key factor affecting the overall performance of firms [6]. Improving organizational productivity is an issue that has been used for some time and will continue to be important. For manufacturing companies characterized by low utilization of their resources (machines/ equipment, human labor, materials, capital, energy, time and others), productivity measurement and improvement is not only desired but is also increasingly becoming a requirement for organizational survival [7].

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Business model CANVAS, Lean Start-up, Organization

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BUSINESS MODEL CANVAS

Abstract

The paper deals with the business model canvas, by which start-ups could outline the process of value creation. Business model as opposed to a business plan guide describes how to create and deliver value (product or service) to customers as well as demand, customer-supplier network or the way the company earns money.

1. INTRODUCTION

The Business Model Canvas or BMC model is a graphic representation of a number of variables that show the values of an organization. The Business Model Canvas can be deployed as a strategy tool for the development of a new organization. Furthermore, it also analyses the (business) situation of an existing business. The Business Model Canvas was developed by the Swiss business model guru Alexander Osterwalder and management Information Systems professor Yves Pigneur [1, 2]. The performance of an existing organization can easily be improved using the Business Model Canvas. All company aspects are made clear at a glance because of the visual aspect [2]. By looking at the developments per category, an organization can fine-tune its value proposition and structurally improve its strategy. When setting up new company clear decisions can be made in advance is using the Business Model Canvas. The Business Model Canvas has nine elements as is shown in Figure 1. There are:

- **Customer Segments:** Who are the customers? What do they think? See? Feel? Do? Which classes are you creating values for? Who is your most important customer? [3] As organizations often provide services to more than one customer group, it is sensible to divide them into customer segments.
- **Value Propositions:** What's compelling about the proposition? Why do customers buy, use? What core value do you deliver to the customer? Which customer needs are you satisfying? The value proposition is about the core of a company's right to exist, it meets the customer's need. [4].

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- **Distribution channels**: How are these propositions promoted, sold and delivered? Why? Is it working? Through which channels that your customers want to be reached? Which channels work best? How much do they cost? Channels to customers have five different stages: awareness of the product, purchase, delivery, evaluation, satisfaction and after sales [5, 6].
- **Customer Relationships:** How do you interact with the customer through their journey? What relationship that the target customer expects you to establish? It is essential to interact with customers. The broader the customer base the more important it is to divide your customers into different target groups.
- **Revenue Streams:** How does the business earn revenue from the value propositions? For what value are your customers willing to pay? What and how do they recently pay? How would they prefer to pay? How much does every revenue stream contribute to the overall revenues? The revenue streams are cost drivers. In addition to the revenue from the sale of goods, subscription fees, lease income, licensing, sponsoring and advertising may also be an option.
- **Key Activities:** What uniquely strategic things does the business do to deliver its proposition? By having a good knowledge of the core activities of a company, a good understanding of the value proposition of the organization will be obtained. It is not just about production, but also about a problem-solving approach, networking and the quality of the product and/or service. When the organization knows what the added value for the customer is, a better relationship may develop with existing customers, which may be helpful in the canvassing of new customers therefore, and which makes it easier to keep the competition at bay.
- **Key Resources:** What unique strategic assets must the business have to compete? What key resources does your value proposition require? Resources are means that a company needs to perform. They can be categorized as physical, intellectual, financial or human resources. Physical resources may include assets such as business equipment. Intellectual resources include among other things knowledge, brands and patents.

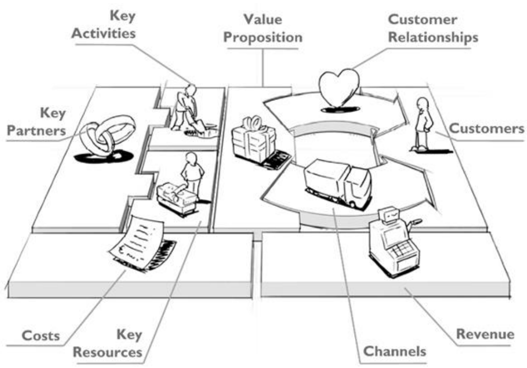

Fig. 1. Business model Canvas

- **Key Partnerships:** What can the company not do so it can focus on its Key Activities? Who are your key partners/suppliers? What are the motivations for the partnerships? For start-up organizations and existing organizations it may be important to create alliances with partners. For instance when fighting the competition and combining knowledge and specialization. Essential information will be acquired by knowing in advance which partners may constitute a valuable relationship.

- **Cost Structure:** What are the business' major cost drivers? How are they linked to revenue? The cost structure considers economies of scale, constant and variable costs [6].

2. PRACTICE EXAMPLE OF BUSINESS MODEL CANVAS

What are the three characters prospective startup? There are:
- Around the vision that has changed the world is established an implementation team.
- Start-up developed unusual technological solutions that provide customers with clear benefits.
- Start-up knows their few customers, from which they receive for their product a positive response.

The business model canvas as opposed to the traditional, intricate business plan helps organizations conduct structured, tangible, and strategic conversations around new businesses or existing ones. Leading global company like Nestlé use the canvas to manage strategy or create new growth engines, while start-ups use it in their search for the right business model. The canvas's main objective is to help companies move beyond product-centric thinking and towards business model thinking. Alexander Osterwalder in Harward business review [3] provides the example of business model canvas for produts Neopresso. Nespresso, a fully owned daughter company of Nestlé, is a great example of a powerful business model. It changed the face of the coffee industry by turning a transactional business (selling coffee through retail) into one with recurring revenues (selling proprietary pods through direct channels). An innovative approach to the development of corporate strategy, which takes into account all elements of the business model and looking for their optimal combination, illustrated by the example of Nespresso products is shown in Figure 2.

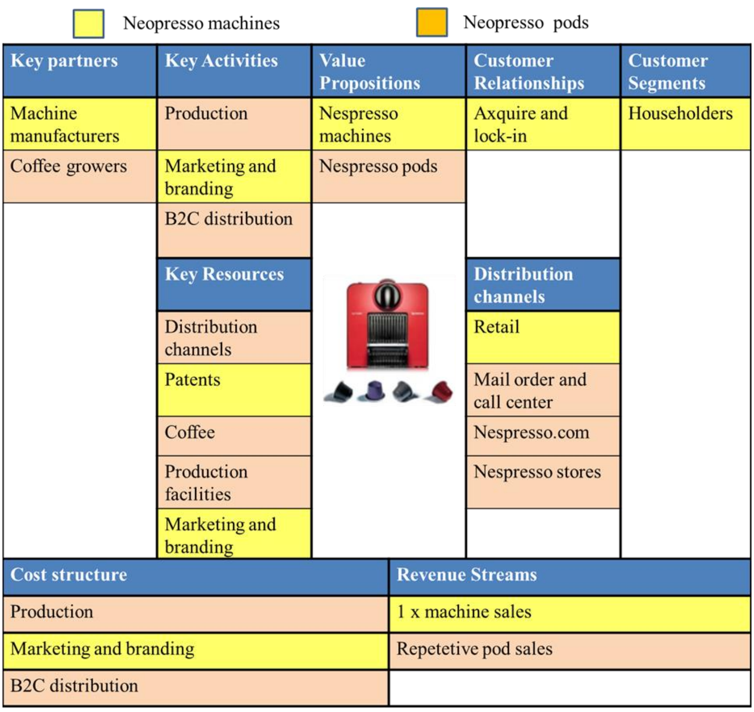

Fig. 2. The example of Business model Canvas – Nespresso

3. CONCLUSION

Methods of reducing risk in the process of setting up a startup called Lean Start-up. Lean founder of start-up, Eric Ries [8], applying the so-called lean thinking in the process of innovation. The first strategic step lean start-up is to search for the key areas of the business model (Customers, distribution channels, partners, value by product or services, etc.) and the formation of hypotheses. Summary of hypotheses into a coherent framework provides tool - a business model canvas through which startup can outline the process of creating enterprise value and customers.
The strategy of the traditional approach is based on the business plan and its implementation.When someone decides to start a startup and has a clear idea what the product (how big the market is, for whom the product or as a priority is intended). Failure often comes at a moment when the potential investor or partner asks: How you want to achieve defined goals?
Start-ups, especially if it is their first start-up attempt, not at all clear about the strategy "go to market". It is important to clarify the budding entrepreneur all follow-up product to market penetration and contingencies involved. Apply the basic rule - the entrepreneur must have a well-developed plan properly consulted with relevant mentors and not be afraid to update it.

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Scheduling of production processes, Production process

Szymon PAWLAK[*], Łukasz POLOCZEK[**]

UNDERESTIMATION OF TIME FOR IMPLEMENTATION OF TECHNOLOGICAL OPERATIONS DUE TO ERRORS IN THE PROCESS OF SCHEDULING

Abstract

Underestimation of time for implementation of technological operations is the primary cause of errors occurring during the scheduling process. Creating a timetable, which does not reflect production reality, makes it impossible to determine the company's production capacity and define a long-term plan of work within a single manufacturing process. The article presents the impact and effects of underestimation of the duration of technological operations on a schedule, as well as the level of underestimation of the data derived from it.

1. INTRODUCTION

The design, construction and implementation of a properly functioning production schedule is the basis for determining the company's production capacity, the duration of the production process and the start and end dates for subsequent technological activities carried out in a single production process. The complexity of production in terms of technology, planning and organizational processes, as well as the dynamic nature of operations and the risk of occurrence of unexpected factors, makes it difficult to make timely decisions that have the desired effect of synchronizing theoretical time with the actual duration of operations [1].

In order to build a schedule (as close as possible to the reality of production), a number of methods are used to optimize its form. According to the assumption, the optimization of the production schedule is based on correlation of its parameters with the actual course of the manufacturing process. The use of methods to optimize the construction schedule and the production timetable is dedicated to strictly defined processes with low variability, which prevents their widespread use [1].

The absence of algorithms to ensure that production parameters are fully reflected and predicting all kinds of irregularities affecting the quality of the schedule determines the need for continuous control of the manufacturing process and the introduction of corrections to unify

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the obtained data, both theoretical (calculated in the process of estimation) and factual (verified during the manufacturing process).

2. SCHEDULING OF THE PRODUCTION PROCESSES

Scheduling of the production processes is a complex operation that consists of many stages defining elementary decisions and organizational issues [2, 3]. One of the basic stages of the scheduling process is to create a mathematical model that defines the manufacturing process along with its limitations, as well as criteria for evaluation of the obtained data [2, 3]. In order to build a properly functioning model, it is necessary to identify the production and organizational resources that are available and evaluate their characteristics and constraints affecting the manufacturing process. Subsequently, it is essential to describe the technological process along with its correlations, both quantitative and qualitative, and specify the technological limitations. Finally, the ultimate set of production orders is defined, including all information concerning, inter alia, the number of items produced and the expected time of production [1].

Correct execution of all stages of the scheduling methodology does not, however, reflect the results obtained in the production practice. The basis for the implementation of a proper (realistic) schedule is to precisely define the input data. The most frequently encountered problem causing inaccuracies is the lack of proper estimation of the execution time of particular technological operations involved in the considered process [4].

The time needed to complete the technological operation should be determined on the basis of the knowledge related to the value of working time, which must be dedicated to performing specific production tasks under strictly defined conditions and a standardized methodology for their execution. There is a large number of methods for estimating the time of the selected technological operation. The most commonly used methods include analytical and measurement methods (timekeeping, snapshot monitoring, daytime photography), analytical and computational methods (MTM norms, norms of work according to technological standards), as well as analytical and comparative methods (comparison and estimation). The effectiveness and accuracy of the results depends on the type of production and its repeatability [4].

3. THE CONSEQUENCES OF UNDERESTIMATION OF TIME FOR REALIZATION OF TECHNOLOGICAL OPERATIONS

Incorrect timing of technological operations may lead to misdiagnosis of the production capacity of the selected company or imprecise estimation of the lead time of the selected batch. The article analyzes the level of underestimation of one of eight technological processes implemented in the production process and its impact on the way the entire manufacturing process is performed. The analyzed operation was carried out continuously at one workstation by one operator. During the repetitive operation, other production work was not carried out, which extended its duration.

On the basis of the conducted analytical-measurement methods, the theoretical duration of the technological operation was determined - 100j. The operation was analyzed seventy times, Fig. 1. The average execution time of the operation amounted to 111j, thus, it exceeded its theoretical duration causing a total delay of 943j. The difference between the longest and the shortest execution time (interval) amounted to 33j.

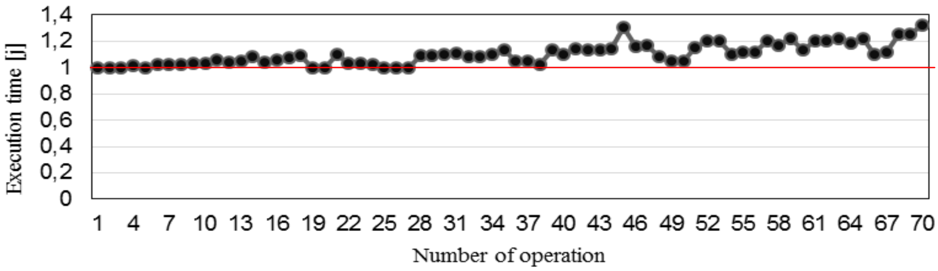

Fig. 1. Time of production operation

The occurrence of delay resulted in 10 fewer operations during the estimated duration of the production causing a decrease in the productivity and production capacity of the plant, which directly contributed to delays in other production sites, Fig. 2.

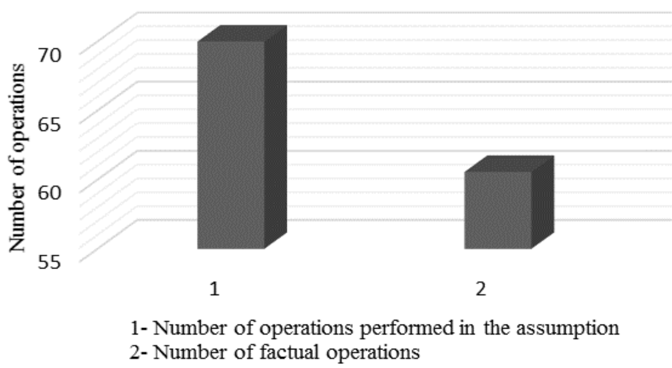

Fig. 2. Number of operations scheduled and executed within a specified time

Delays may result in an increase in inventories between operational and production downtime, which directly affects the decline in control and compliance of actual data (acquired during the manufacturing process). This fact makes it impossible to specify the production plan within a strictly defined time frame and to define the exact time of the chain of technological operations.

4. CORRECTION FACTOR FOR UNDERESTIMATION

One of the possibilities allowing for obtaining a higher level of convergence of technological operations defined by analytical methods (with those generated during the manufacturing process) is to determine the factor which defines the level of their underestimation.

$$C_r \approx C_t \cdot W_d \quad (1)$$

where: Cr- actual time of operation, Ct- theoretical time, Wd- estimation factor

The methodology allowing for determining the underestimation factor consists of the division of technological operations into standardized criteria describing the complexity of the operation, the level of automation, the duration of the operation and the degree of repeatability. Subsequently, statistical methods should determine the level of discrepancies in the data. The division of operations due to the criteria assigned to them means that the use of the correction factor for underestimation is not limited to selected process groups or industries, making it a universal tool for better designation of manufacturing process parameters at the schedule construction level. Even a slight increase in the convergence of theoretical and factual time obtained by using the correction factor- Cr will allow for a more accurate estimation of all manufacturing parameters (describing the company's production capacity), which will directly affect the quality of the production schedule and the obtained data.
One of the problems that arise during the process of acquiring the estimation factor is the need to obtain a large amount of data describing the selected type of production operation. It is assumed that the increase in the number of collected results will allow for a more accurate estimation of the factor and a reduction in the differences between the theoretical and factual time of performance.

5. SUMMARY

Scheduling of the production processes is the primary operation that allows to systematize the process, plan the production activities and acquire the company's production capacity data. High complexity of the data and its rate of change makes it difficult to build a model that faithfully reflects the reality prevailing during the manufacturing process. One of the ways to reduce the disproportion is to use a correction factor -Cr.

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Smart hospital, AGV system, logistics, health care system, improvement

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HOSPITAL OF THE FUTURE

Abstract

This paper provides general information and characteristics of smart technologies used in health care facilities. Authors describe AGV system components, the application and benefits of AGV system in selected health care facility. The final part also contains the economic evaluation of this implementation and further investments related to this technology.

1. SMART HOSPITAL

The creation of modern and friendly health care environment, based on smart technologies can make a major contribution to creating a better environment for patients, and thus an increase in the quality and level of service provided by the healthcare facility. Health care facilities all over the world are transforming into intelligent facilities.

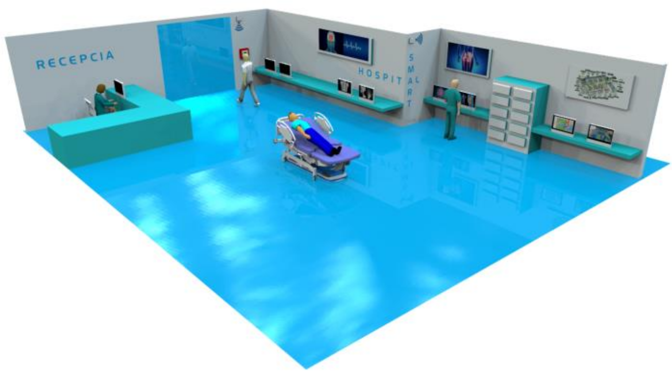

Fig. 1. Smart hospital

Since the design and layout of a healthcare facility is a very important element from a SMART healthcare perspective, it is expected from the designers of new facilities that their designs of

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buildings will meet the needs of both patients and healthcare professionals from the view of using SMART technologies. The SMART concept of health care facility should be designed to achieve the following goals:

- Safety and clinical quality.
- Productivity.
- Easy to use for patients, doctors, families and caregivers.
- Excellence of health services.
- Optimal use of health technologies, information and patient protection.

The operational layout of the hospital and the use of SMART and modern logistics systems significantly affect the operation of the entire facility and its economy, improves the quality of care for patients and increases their safety. In the following chapter we will introduce you the AGV system that represents an intelligent and smart way of internal logistics of modern hospitals. This system is represented by automated carts for food, medical / surgical supplies, bed linen, scrap, medical waste, pharmaceutical products, items for decontamination centers and general household items transportation.

2. AGV FOR HEALTH CARE FACILITIES

Automatic Guided Vehicles (AGV) or self-guided vehicles (SGV), have been widely used in material handling for decades [1]. In these days, the demand for mobile robots and their use in hospitals has increased due to changes in demographic trends and medical cost control. For healthcare facilities, these automated systems are designed specifically for a bulk material handling, pharmacy medicines, laboratories samples, central supply and food transportation, dirty dishes, bed linen, waste (biological, recyclable), biomedical instruments etc. Operating efficiency is gained by automating these supplies, which allows the transfer of human resources to other departments or activities. Automated systems are working 24 hours a day, 7 days a week. Automated solution can streamline traffic flow of material in the hospital, control costs, reduce workload. Hospital operating installation and use of modern logistics systems significantly affects the operation of the entire facility and its economy, improves the quality of patient care and increases their safety. [2] In the hospital, this AGV system connects areas of central processes such as kitchens, laundry, trashdock, sterilization departments, etc. With Patient Units (so-called patientfloor). The materials are processed in these areas and are sent automatically using the Automated Transport System (ATS) to the appropriate floor.

2.1. The visualization of AGV integration in simulation software SIMIO

The use of automated transport system (AGV) relieves hospital staff and allows them to spend most of their time on direct patient care. This increases safety in the hospital by minimizing potential injury to the hospital when pushing heavy carts. The system monitors all major movements in the hospital and may prefer the most important jobs and tasks that can be completed first (e.g. surgical instruments transported first, then food for patients, bedding, eventually garbage, etc.) [3]. AGV is equipped with sensors to detect obstacles that allow safe stop before hitting obstacles that might be in the way. The system and its vehicles is reliable, safe, efficient and cost-effective [4]. Applications and commands are mediated through a user-friendly touch screen. The system is fully integrated for automatic control of doors, elevators, trolley washers, garbage dump truck, etc. We use simulation software to verify and check our suggested implementations of AGV in inpatient ward. For this purpose, we used software

Simio in which we have imported the real objects and the physical disposition of healthcare facility. Figure 2 shows the transportation process of food in the hospital in digital environment. AGV in this simulation software follows the inpatient ward streams that we have mapped and analyzed (i.e. The movement of medical staff). Transport between the floors will be carried freight elevator. (Fig. 2.). Vehicle will then transport the food to a designated locations of patient rooms.

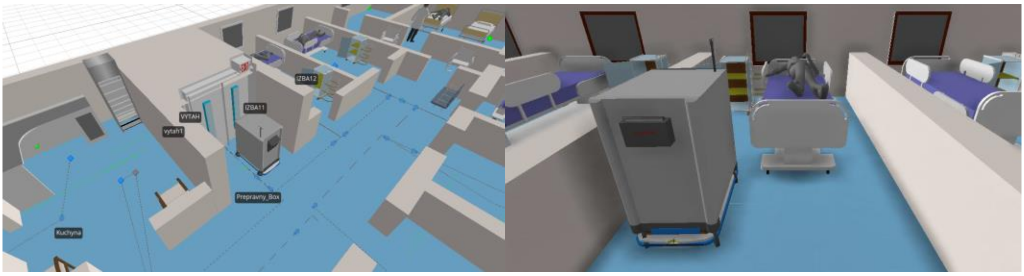

Fig. 2. Food transportation to the inpatient ward by freight elevator; food unloading in patient room

2.2. The benefits from AGV integration gained from simulation runs

With the AGV integration we were able to save 345 minutes of total 1440 minutes (representing 23.96%) for medical assistant (MA). This can result in the transfer or movement of medical assistants to activities and tasks that enable them to carry out legislation [5]. Furthermore, we will be able to relieve the cleaning services from transporting the heavy and dangerous waste by AGV system integration. Among other things, the AGV can be also used for transportation of medicines and medical supplies with low requirements on safety or hygiene. This integration will bring benefits associated with the reduction of damage, unreasonable and incorrect shipments, and physically heavy transport. Another advantage is that the vehicle can operate 24 hours a day while meeting the requirements of charge.

2.3. Economic evaluation

The final chapter brings the economic evaluation of AGV integration in selected healthcare facility. To calculate the hourly costs for running an AGV we used input costs, which are around € 115,700. From these calculated costs we expressed our monthly operating costs of 4% (specified by the AGV manufacturer), representing a value of € 4,628/month. From this value we expressed the operating costs necessary for one day provision (€ 154.27/day). In the last stage of the calculation, we found the hourly cost of running the AGV at around € 6.43/hour. These values were then compared to the hourly cost of medical assistant for inpatient ward (€ 3.5) from which we can see that operating costs of AGV are almost 2 times higher. And although this is a rough calculation of operating costs, it gives an approximate idea to the managers of health facilities whether it is good to think about the implementation of this technology.

Tab. 1. Hourly operating costs

Operator	Operating costs per hour (€)
Medical assistant	3.5
AGV	6.43

3. CONCLUSION

Case study, which we have tried to briefly introduce to you in this article was carried out at the request of the director of healthcare facility in order to identify the potential implementation of AGV system in the hospital. In the case study, we designed AGV and transport methods for inpatient ward in healthcare facility. This way of transport we subsequently created in a 3D environment where we have simulated and verified the movement of. The final economic assessment then pointed out that the AGV technology is currently not cheap and is affordable only by bigger facilities managing in profit. Proper and effective implementation for a given type of healthcare facility depends on many factors and requires a detailed assessment and analysis [6].

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Simulation, Health care, Decision making tool, management

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SIMULATION AS A DECISION MAKING TOOL

Abstract

In this article the authors describe the simulation as an industrial engineering tool that is appropriate and useful for many fields in health care sector. The second part is then devoted to simulation as a support tool for management and offers a concept and the role of simulation model in the decision making process. The paper also contains recommendations about the future trends and potentials of simulation in health care.

1. THE USE OF SIMULATION IN HEALTHCARE

Simulation has a broad potential of applications in healthcare, which may be classified into several main directions. General classification of simulation in healthcare is as follows:

- *Clinical simulation* – used mainly for studying, analyzing and replication of some diseases behavior, including biological processes in the human body.
- *Operating simulation* – used mainly for capturing, analyzing and studying the health operations, service provision, planning, healthcare operational processes and patient motion.
- *Management simulation* – used primarily as a tool for management purposes, decision making, policy implementation and strategic planning.
- *Training simulation* – used for training and educational purposes, where virtual environments, virtual and physical objects are widely used and enrich simulation experiments.

Managerial and operational direction of the simulation are closely linked. Together, they form the major components for the management of healthcare processes. The above classification is just the starting point, that only indicates huge space of simulation application for healthcare domain. In each of these directions can be simulation used for analysis and design, education and training, research and communication purposes.

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1.1. Simulation in health care and its potential areas and future trends

Simulation in healthcare primarily allows the replication of the facts and examination of possible changes and situations that were not really possible. This can be achieved without high investments in systems development, training, and equipment purchasing [1].
Moreover, simulation in health care may be extended beyond its traditional role of scenarios comparison and workflow visualization. The simulation model can be incorporated as a part of ongoing efforts of performance monitoring and efficiency improving. In this role the simulation model is developed not only for the runs and experiments, but is rooted in the information systems of health care facility.

1.2. Decision support

Simulation in health care can be considered as an effective tool, technique or method [2]. Healthcare personnel especially decision makers - directors and managers need reliable operational tool that supports them in decision-making process. Such techniques and tools help them in reductions of costs, waiting time of patients, future predictions of patients arrivals and provide them with visualization that enables them to prepare staff and all resources that are necessary for provision of high quality healthcare to patients at the right time. These tools should also facilitate the decision making evidence and informative environment. Simulation models, especially those with transparent structure to the core variables that can be easily understood and trusted by people with decision-making competence, are a useful tool to support decision making, communication, discussion, ideas, policies, scenario analysis, from which they can gain knowledge and from which they can learn [3]. That was also our case, since we needed to create a simulation model of a real healthcare facility that will help the management to decide whether to implement the AGV system. After many interviews with the leadership we have created several model variants. Whereas the creation and process of a simulation study is very extensive, in the next chapter, we bring and summarize the most important outcomes and results that were the key ones for healthcare managers.

2. EMERGENCY DEPARTMENT SIMULATION MODEL

Simulation is the imitation of actual running process in time. [4] By emulating logic and randomness of the process, such as the flow of patients through the various departments of medical facilities and random duration of each type of treatment, simulation is a valuable tool for the evaluation and comparison of the proposed changes to the process.

2.1 The simulation study

An important advantage of using simulation for modeling health care facility over other tools is the ability to model the complex patient flows and testing scenarios and "what if" changes in patient flow management. The success or failure of simulation studies in the field of health care often depends on following the standard sequence of steps. [5] To make the model match the reality, we have to consider also the restrictions. The design of the final ED model is in most cases the same, with minor adaptations and modifications. The model of ED shown in Fig. 1. we have created and verified in software SIMIO. In Fig. 1. there are also shown information that were necessary for real ED design in digital environment.

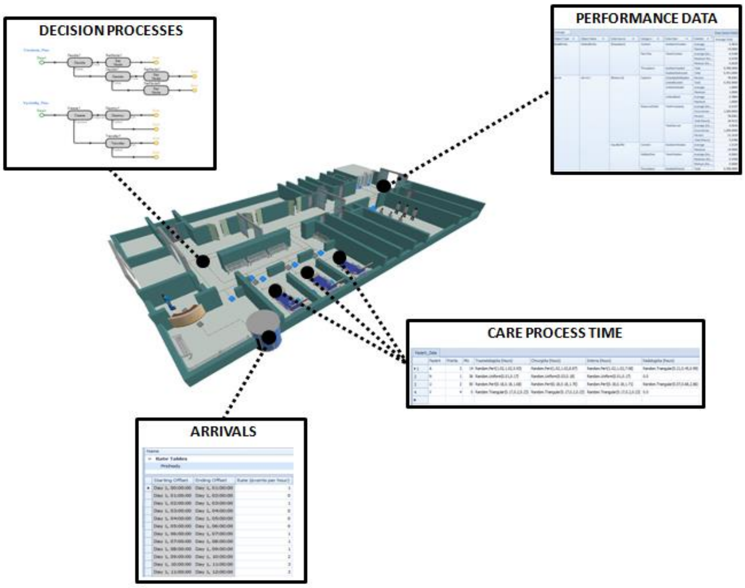

Fig. 1. Simulation model designed in software SIMIO

This is how we have made a great deal of work done and we created a model that will be user-friendly and easy accessible by management in decision-making process. The investigation of effects of new strategies will be made only by change of the desired parameters in MS Excel, which will be automatically restored and updated in the simulation model (Fig. 2.). Thus, leadership do may not have simulation and programming skills to be able to use the simulation potential as a support and decision making tool.

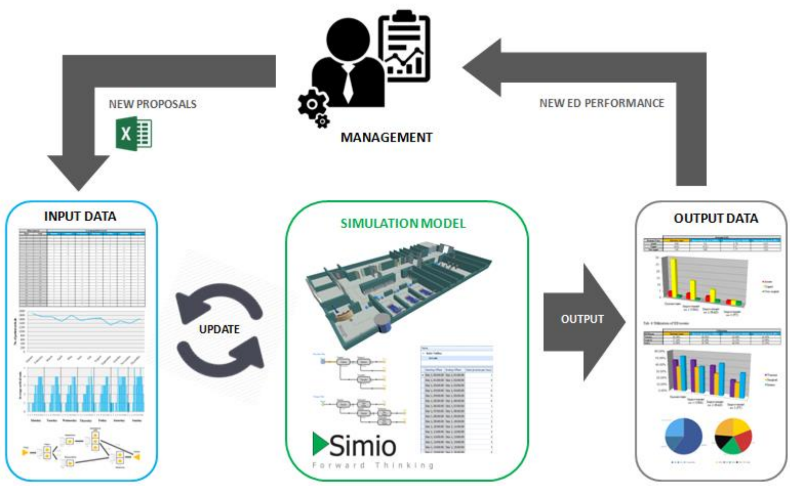

Fig. 2. Simulation as a decision making tool

The structure of information sources that provide support for decision-making should include measured OUP performance, for example by simulation, knowledge should be the next source, i.e., Evidence, experience and historical measured data. When we know at what level our performance is moving, that means we can already quantify our processes, we can begin to increase their performance. [6] As developments, particularly technological, and demand from patient and European Union are constantly on the rise, management should not be satisfied with the current state of performance . The modern healthcare facility should have an effort to continually learn and improve the performance and quality of healthcare provision. Only then can management keep up and compete with the best in the field.

3. CONCLUSION

Traditional forecasting approaches often fail to predict or to analyze changes in conditions of complexity. Experimental approaches allow to simulate the decision-making process under controlled conditions, thus reducing uncertainty of information. At the same time they take into account the complexity of socio-economic, technological and biological factors and motivations that may affect human behavior and decision making, for example, in situations in which individual interests are in conflict with societal. They also allow testing of new alternative policies and decision-making tools, such as the protection of health, natural resources, the introduction of technological and organizational innovation.

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3D printing, Foundry, Aluminum alloys, AlSi5Mg

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APPLICATION OF INCREMENT TECHNOLOGY IN FOUNDRY

Abstract

3D printing technology is an excellent example of an innovative approach to issues related to manufacturing techniques. It finds increasingly wider areas of application. Currently, 3D printing is used not only for manufacturing the finished product, but also can be used as one of the production steps in the production of the target item (especially when we are forced to produce more items). The article presents the use of incremental production in foundry.

1. INTRODUCTION

For several years, 3D printing is an example of a very rapidly developing manufacturing technology. In the beginning, it was only about prototypes reflecting only the shape of the elements. The development of technology enabled the production of not only prototypes, but also spare parts with specific utility parameters [1]. Currently, 3D printing can be used as one of the production steps in the production of the target item - especially when we are forced to produce more items. The use of 3D printing allows to skip or at least substantially reduce the steps of preparing the physical model needed to make a mold [2].

2. RESEARCH MATERIAL AND METHODOLOGY

Material for the research consisted of AlSi5Mg aluminum casting alloy. The chemical composition of the alloy is shown in the Tab. 1.

Tab. 1. Chemical composition of the AlSI5Mg alloy (wt. %).

	Si [%]	Fe [%]	Cu [%]	Mn [%]	Mg [%]	Zn [%]	Al
PN-EN1706 norm	5,0÷6,0	0.19	0.05	0.10	0.25÷0.45	0.07	rest
Specimen	5.80	0.14	0.002	0.004	0.27	0.008	rest

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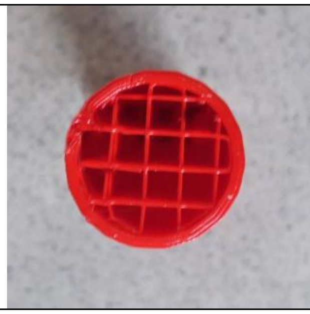
The material was cast into gypsum molds in the form of cylinders with a diameter of ø20 and a length of 100 mm. Physical model of a cylinder (Fig. 1.) was made in 3D printing technology on the ZMorph 2.0 S printer. The physical model was printed from CR3DIMENSION's PLA filament with the following parameters: extruder temperature: 220°C, hotbed temperature: 90°C, leyer height: 0.2 mm, infill ratio: 15%, travel speed: 120 mm/s, bottom layer base: power raft PLA.

a)



b)

Fig. 1. a) Physical model of cylinder; b) Infill ratio of printed cylinder

The printed cylinder model was placed in gypsum form (Fig. 2.). In one of the form the physical model was melted in the furnace and the other molds were flooded directly with molten aluminum (750°C) without removing the physical model.

a)

b)

Fig. 2. a) Gypsum mold; b) Gypsum mold with the physical model of the cylinder

3. RESERCH RESULTS

Obtained castings and the reference sample are shown on Fig. 3. Sample cast into gypsum mold without physical model was characterized by much more rough surface than the reference sample. This difference appears probably due to incomplete drying of the gypsum mold. In turn, the sample cast directly into a gypsum mold with a physical model was characterized by burnt surface. The scorching of the surface occurred as a result of the contact and reaction of the liquid metal with the PLA material. The microstructures of the obtained samples are shown on Fig. 4. and 5. Microstructure of all tested samples was characterized by the finest α-Al dendrites and eutectic Si crystals. The reference sample was characterized by the smallest porosity. Only a few small shrinking pores occurred in this specimen. In the Sample cast into gypsum mold without physical model numerous gas pores have been observed and eutectic silicon crystals have appeared to be more widespread. In turn in the sample cast directly into a gypsum mold with a physical model was characterized by the presence of numerous gas and shrinkage pores. In this case, eutectic silicon crystals were much more developed than in the two previous samples.

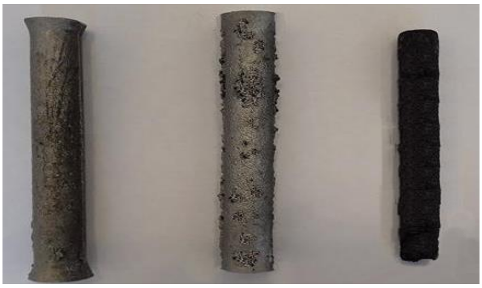
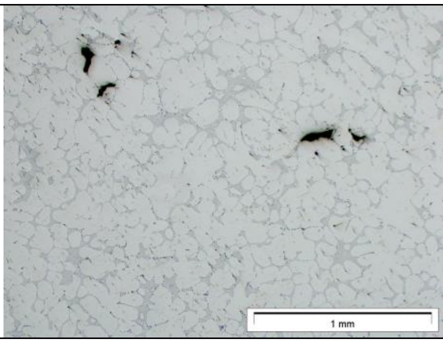


Fig. 3. a) Reference sample gravity cast into a sand mold; b) Sample cast into gypsum mold without physical model; c) Sample cast directly into a gypsum mold with a physical model



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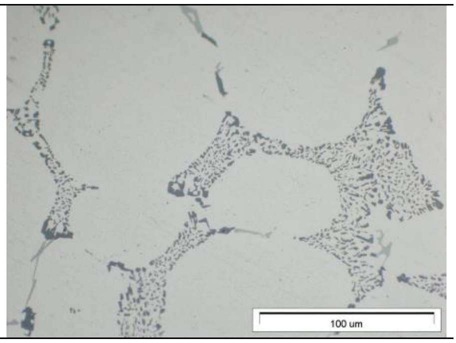

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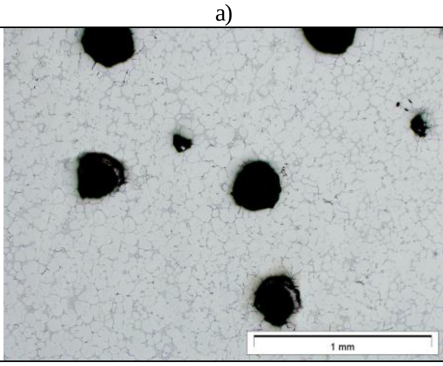

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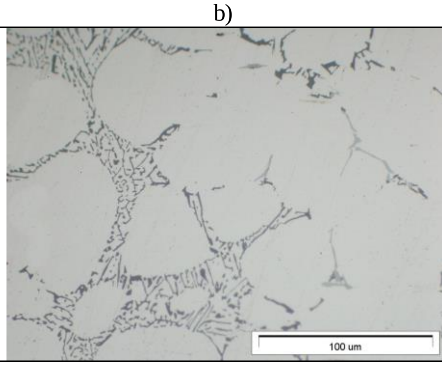
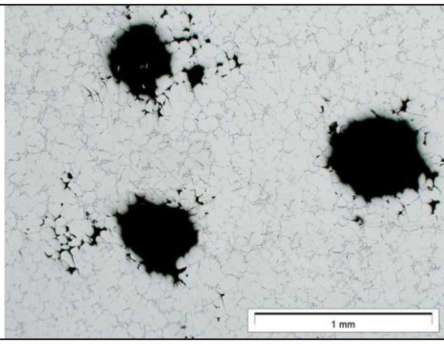
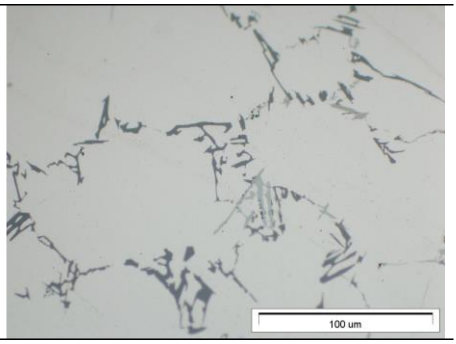


d)

Fig. 4. a, b) porosity and microstructure of reference sample; c, d) porosity and microstructure of sample cast into gypsum mold without physical model



a)



b)

Fig. 5. a, b) porosity and microstructure of sample cast directly into a gypsum mold with a physical model

4. SUMMARY

1. Contact of liquid melt with wet gypsum mold caused excessive release of reaction gases which resulted in excessive gasification of the melt. In order to achieve a casting characterized by steady properties, it is necessary to dry the mold or use another material.
2. Contact of the molten alloy with the PLA filament caused carbonize of filament on the surface of cast. The combustion reaction between the liquid alloy and the filament caused the gaseous of the alloy. In order to avoid a rapid combustion reaction it is necessary to use a filament which will be characterized by lower melting point.
3. Large gasification of liquid alloy and the growth of crystals of eutectic silicon greatly deteriorated mechanical properties of the alloy.

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Production process design, Modeling, Target costing, Kaizen costing

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KAIZEN COSTING AS SCHELETON OF LEAN MANUFACTURING BASED ON TOYOTA

Abstract

The term lean production is defined in the paper, and its components are characterized. The production costing methodology (kaizen costing) has been described. Define the factors of the production system on which the costs of the process are dependent. The structure of the lean production concept is illustrated as the Toyota Production System (TPS), demonstrating the predominant influence of kaizen costing on streamlining the process.

1. INTRODUCTION

The protagonist of the concept of lean manufacturing is the Toyota Production System. This concept covers activities to streamline the manufacturing process including product development, procurement, manufacturing, and customer relationships. The TPS system was developed after the end of World War II, was created and put into production at the Toyota plant by T Ohno. The Lean Production / Management concept was not entirely new. It evolved in time since 1914, when H. Ford applied its prototype factory in Highland Park in Detroit. [1]

2. TOYOTA PRODUCTION SYSTEM AND KAIZEN COSTING

The Toyota Production System is shown in Fig. 1. One of the basic elements of the rationalization of production processes are the activities falling within the kaizen concept and the associated costs of their implementation and the expected effects of the application.

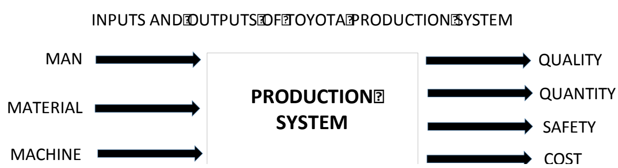

Fig. 1. Structure of the Toyota Production System - own elaboration on the basis of [3]

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In order to be able to define the cost relationships of the production system, it is necessary to define Toyota's cost of production / product. Toyota is pioneering the implementation of the concept called "Target Costing" and "Kaizen Costing". According to Y. Monden by Target Costing" ("Genkankaku" in Japanese - setting the target cost and how to achieve it), it should be understood as supporting the cost reduction process in the development and design phase of a completely new product or its change, Kaizen Costing ("Genkakaizen" in Japanese) is a system to support the process of cost reduction in the production phase of the manufactured product. Extremely important in the definition of "Kaizen Costing" is to emphasize the focus on the production process as opposed to the "Target Costing" design and product structure. The TPS system consists of two pillars: "Just in time" and "Jidoka".

Fig. 2. Structure of Toyota Production Systems - own elaboration on [3]

The "Just In Time" pillar is defined as the supply, manufacture and transport of good products in the right quantity and time. It consists of 3 elements: production based on continuous flow, drawn production system, production based on tact time. In order to ensure a continuous flow of production, it is necessary to conduct it on the basis of a sequential system, controlled in a tactile manner.

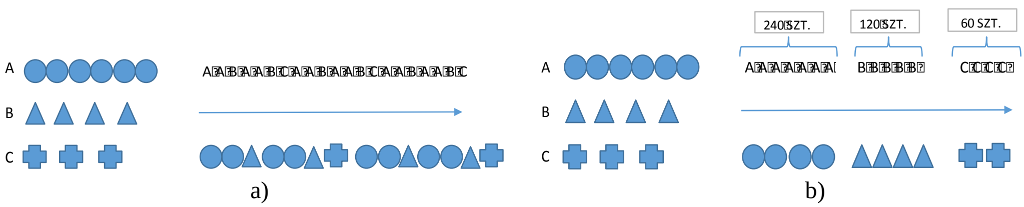

Fig. 3. a) Sequential production based [3]; b) Production in batches based [4]

Fig. 3. a) shows the sequence of production with the schedule used in Toyota. Fig. 3. b) illustrates the production in batches where production is controlled by the assumed efficiency and not by the market-driven capacity. The second pillar of the system is "Jidoka - autonomization" also called automation with a human face instead of the standard automation. Autonomization means transferring human intelligence to machines. The idea was initiated by Sakichi Toyoda by designing an automatically reacting loom. His invention immediately stopped the machine itself as soon as the weave was ripping or untangling. In Toyota this concept is applied not only to machines but also to whole production lines and operators. Autonomization secures production before producing incompatible products, eliminates overproduction and automatically stops when an abnormality occurs on the production line. One of the elements of jidoka is poka-yoke, ie. prevention of errors. For example, if a component is wrongly produced, operator will not be able to complete the operation, if it is wrongly attached, the machine will not start, the abnormalities of the previous process are checked, and in the case of anomaly, they can’t reach next process [Ohno].

3. NEW PRODUCT PRODUCTION PREPARATION AND DEVELOPMENT OF COST MANAGEMENT

Methods related to the concept of Target Costing and Kaizen Costing are used to evaluate the cost of preparation and implementation. Target Costing focuses primarily on the phases of preparing a new product. After launching production, it is transformed into cost-minimizing activities through continuous improvement of Kaizen Costing production) [2]. The general essence of target cost accounting can be presented using the following formula (1) i (2) [1]:

$$K_{dproject} = B_{project} \tag{1}$$

where: $K_{dproject}$ – project target cost, $B_{project}$ – project budget

$$K_{dproduction} = C - Z \tag{2}$$

where: $K_{dproduction}$ production target cost, C – price, Z – expected profit

It can therefore be assumed that the target cost of a project is a specified project budget and that the production cost is the maximum allowable cost of production (unit cost of production). In unit production, the low cost production target is the sum of the cost of project implementation, product realization. The costing and costing behavioral approach is shown in Figure 6. The kaizen costing system is a system of consistent and continuous improvement of the technological process, which aims at reducing product costs in every phase of the production process. Target cost accounting serves to reduce costs in the pre-production phase, while the goal of kaizen costing is to reduce costs in the production phase. Only a full reduction of the strategic part of the surplus costs possible in the further phases of the product life cycle allows for the expected profit target set in the target costing phase. [1]

4. METHODS AND CALCULATION KAIZEN COSTING – GENTANI

The word "Gentani" in Japanese means reduction, but also the exact search or exact consumption index. Gentani in Japanese companies with regard to target costs means the development of costs to find a direct indicator of these costs. Definition of cost: cost = gentani x rate. Gentani - the indicator is closely related to the cost and showing the performance of each activity in each department or process.

Working hours - Analyzes indicator Gentani R

$$G_R = Kprod_o / Prod_o \tag{3}$$

where: $Kprod_o$ - The unit cost of the operating hours of the O area for a fixed period
$Prod_o$ – Number of pieces produced in a fixed period

Tools - Analyzes indicator Gentani N

$$G_N = Kn_o / Prod_o \tag{4}$$

where: Kn_o - The unit cost of worn O area tools in fixed okresie
$Prod_o$ – Number of pieces produced in a fixed period

Indirect consumables - Analyzes indicator Gentani MP

$$G_{MP} = Kmp_o / Prod_o \quad (5)$$

where: Kmp_o - Unit cost of consumables consumed by intermediary area O within a fixed period
$Prod_o$ – Number of pieces produced in a fixed period

Other types of costs such as spare parts, foreign services, telephones, small equipment, measuring devices, etc. are analyzed as the sum of the unit costs of the O in the fixed period. Both the Gentani and the other unit costs determine the monthly and annual reduction targets that make up the overall Kaizen Costing effect.

5. SUMMARY

Kaizen costing cost reduction methods are important in TPS. In the "Just In Time" pillar these activities are related to:

- Manufacturing based on continuous flow - continuous flow guarantees no breakage loss, is reduced $Kprod_o$.
- Pull production system - ensures that overproduction and excessive stockpiles are avoided, the cost of direct and indirect materials, spare parts, energy consumption decreases. time-based production - we adjust the number of operators to actual production needs - we reduce the value of $Kprod_o$

In the "Jidoka" pillar Kaizen costing activities are related to:

- Autonomization - the ability of the operator to stop the line, it affects the value of direct cost indicators, the number of defects, the separation of operations between machine and man, $Kprod_o$
- Poka Yoke - any downtime increases the risk of breaking the standard and consequently an accident at work or quality shortages - we affect the rate of work hours and the direct costs of shortfall.

Kaizen costing does not function in isolation from TPS, it is included in the management of this system, helping to achieve cost performance.

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Production design process, Quality function deployment, Target costing

Tomasz SENETA*, Józef MATUSZEK**

TARGET COSTING AND QFD IN MANAGEMENT PROCESSES OF NEW PRODUCTS PRODUCTION PREPARATION

Abstract

The thesis defines the concept QFD function. 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

In recent years, in order to drastically shortened product preparation cycles many corporations and individual companies take steps to step up and improve the efficiency of their work processes. In a variety of collaborating teams, often working in various business entities, they seek collaborative work of product design, process implementation, and execution. These processes should tend to reduce costs. It finds here the use of "target costing" . By Y.Monden Target Costing („ Genkankaku" in Japanese means establishing the target cost and way how to achieve it) should be understood as supporting the cost reduction process in the development and design phase of an entirely new product or change [3]. The target costing concept was created in Japan at the Toyota Motor Corporation in the second half of the sixties of the last century under the original name "*Genka Kikaku"*. R. Cooper i R. Slagmulder (1999: 23) define Target costing as a life-cycle costing behavioral approach that will ensure that the planned product is of the required quality and functionality, and that sales at the expected price will achieve the desired level of profitability. In this view, the target cost account is a strategic management tool not only for costs but also for future financial results [1].

Target cost accounting is one of the most common cost management tools today, and is now gaining more and more popularity outside of Japan. Therefore, the purpose of this paper is to identify factors triggering the implementation and application of target cost accounting in selected countries that have experience in implementation *Target costing*. [7]

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2. TARGET COSTING IN NEW PRODUCTS PRODUCTION PREPARATION

The course of the design process
In large-scale production, launching of new products due to high volume and co-operation of production, the project and its planned implementation effects should be realized with a great emphasis on the manufacturability of the design, especially from the assembly point of view, logistic solutions for the flow of resources, to minimize the time and cost of execution while providing operational effects. Documentation should be characterized by the discipline of budget implementation foreseen for project implementation, the minimum number of errors, the elimination of which at the stage of production costs and times.- Fig. 1.

Target costing
The Japanese explanation of the essence of target cost accounting is stated in the statement that target costing is a cost management instrument that serves to reduce the cost of a product in all phases of its life cycle through the involvement of R & D, design, manufacturing, marketing and accounting departments. [8]
According to the German approach [3], target cost accounting is defined as a set of planning, control and cost management methods used in the early phases of product design and manufacturing, oriented on adapting the cost structure to market requirements.
In the internal value chain of the enterprise, the target cost accounting method consists of three main stages [4]

- Determining the acceptable cost of the product,
- Determine the target cost of the product,
- Determining the cost of the target product components. [1]

Methods related to the concept of Target Costing and Kaizen Costing are used to evaluate the cost of preparation and implementation. The Target Costing concept focuses mainly on the phases involved in preparing the new product. After launching production, it is transformed into cost-minimizing activities through continuous improvement of Kaizen Costing production) – (Fig. 1.).

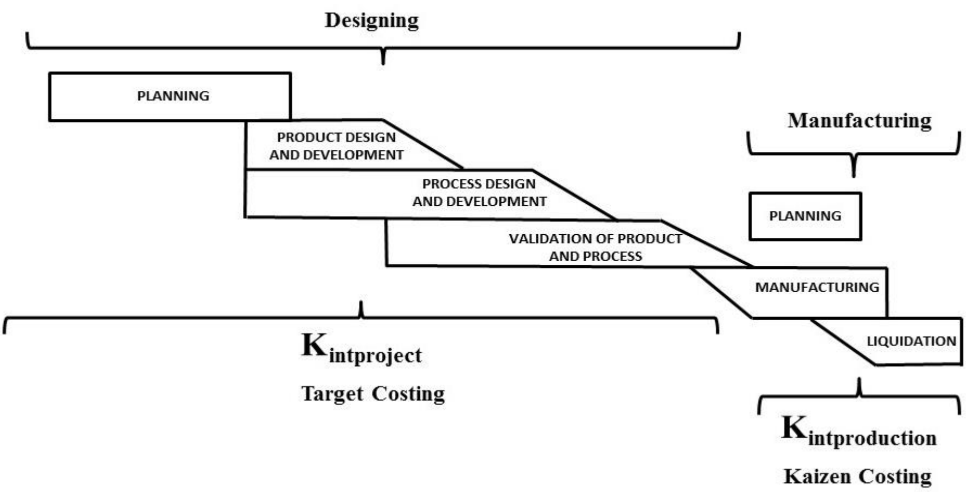

Fig. 1. The scope of application of the concept of Target Costing and Kaizen Costing

The general essence of target cost accounting can be presented using the following formula (1) i (2) [7]:

$$K_{dproject} = B_{project} \tag{1}$$

where: $K_{dproject}$ – project target cost, $B_{project}$ – project budget

$$K_{dproduction} = C - Z \tag{2}$$

where: $K_{dproduction}$ production target cost, C – price, Z – expected profit

It can therefore be assumed that the target cost of a project is a specified project budget and that the production cost is the maximum allowable cost of production (unit cost of production) [7]. In unit production, the low cost production target is the sum of the cost of project implementation and product realization.

3. QUALITY FUNCTION DEPLOYMENT

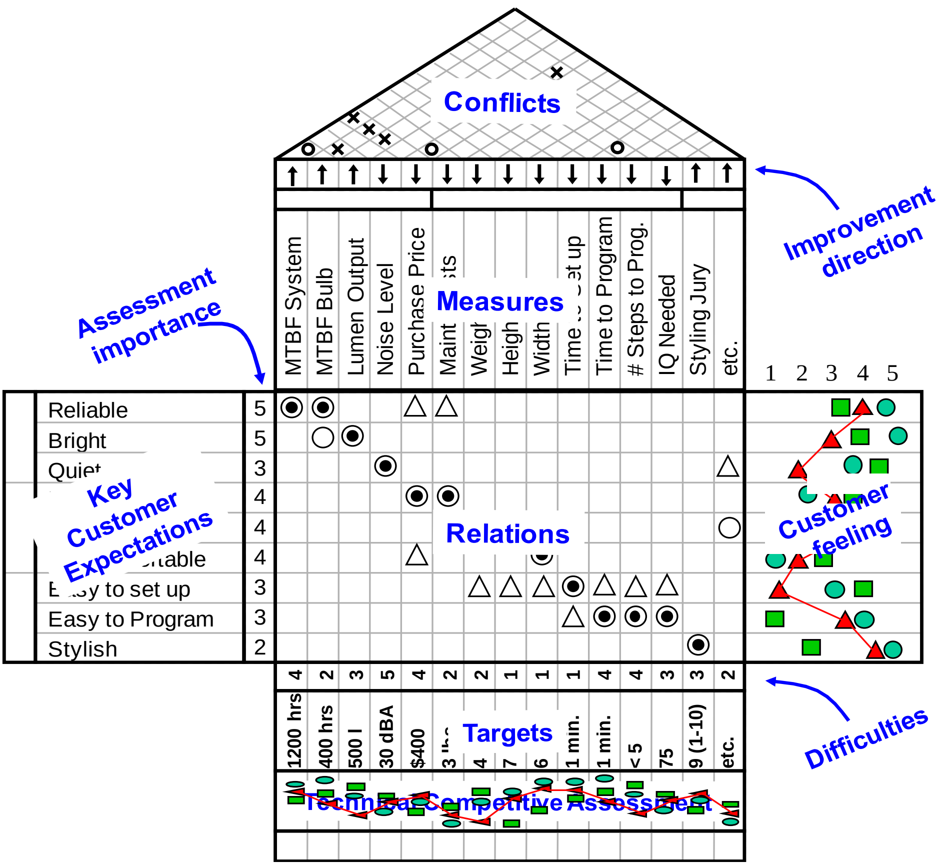

Fig. 2. Diagrams used in the QFD method

In Polish literature the QFD method is translated as "development of quality function". The QFD method has been developed to improve customer satisfaction through process design and production systems [2].
QFD generates four different diagrams or arrays. The first of the arrays, referred to as the planning matrix, aims to transform the "voice of the customer" into "equivalent characteristics". The second matrix, called the advanced matrix, disagrees with the expectations of the product or service for the requirements of the major components. The third matrix is the "matrix of the planning and quality control process" that identifies the critical control points, thus ensuring the control of the features of the products or services and their components during the manufacturing process. The last, fourth matrix, called "operational matrix", helps to transform critical evaluation of product, service, or component parameters into operating instructions used by process handlers. [4].

4. SUMMARY

The QFD Target Costing methodology is designed to best define the target cost and target cost associated with customer expectations, business strategy, and production start-up in line with the plan. The use of such combined schemes in the preparation of production gives very good results - as shown below.
Research [6] has shown that the use of the QFD method gives the company tangible benefits, including:

- Reduction of technological changes by 30% -50%,
- Shortening design cycles by 30% -50%,
- Reduction of production startup costs by 20% -60%,
- Reduce the number of customer returns by 20% -60%.

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The 14 principles of the Toyota way, e-Kanban system, RFID

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INDUSTRIAL SUPPORT OF KANBAN SYSTEM

Abstract

Kanban is a popular framework used by software teams practicing agile software development. It is enormously prominent among today's agile software teams, but the kanban methodology of work dates back more than 50 years. Easy-to-use web-based e-Kanban system was developed to improve the typical manual kanban system. The supply chain of complex assembly systems can be automated easily using industrial RFID solutions.

1. THE 14 PRINCIPLES OF TOYOTA

The expression Lean is used for description of efforts to eliminate losses and waste in corporate processes, as well as for denoting tools, which are used to achieve this goal. Lean methods and tools were pioneered by Toyota, which is well known for its systematical and tireless attitude to loss and waste elimination. [1]

Toyota´s main creator of success is its corporate culture, which extends to every field of business, starting with model designs, through suppliers to the end customer. Toyota´s corporate culture is based on adherence to its fourteen principles. [1]

The eighth principle says: Use only reliable, thoroughly tested technology that serves your people and processes.

- Use technology to support people, not to replace people. Often it is best to work out a process manually before adding technology to support the process.
- A proven process that works generally takes precedence over new and untested technology.
- Conduct actual tests before adopting new technology in business processes, manufacturing systems, or products.
- Reject or modify technologies that conflict with your culture or that might disrupt stability, reliability, and predictability.

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1.1. Six rules for effective Kanban system

Toyota applies 6 rules for effective managing of the Kanban System [2]:

1. Customer (downstream) processes withdraw items in the precise amounts specified by the Kanban.
2. Supplier (upstream) produces items in the precise amounts and sequences specified by the Kanban.
3. No items are made or moved without the Kanban.
4. A Kanban should accompany each item, every time.
5. Defects and incorrect amounts are never sent to the next downstream process.
6. The number of Kanbans is reduced carefully to lower inventories and to reveal problems.

2. E-KANBAN SYSTEM

In easy-to-use web-based e-Kanban system especially designed for production and logistics all movements of the Kanban cards are recognized by barcode reader. This simple principle provides all information in real time, Kanban signals are sent automatically and the Kanban system can be optimized continuously. [3]

2.1. Perspectives of e-Kanban system

From Supplier / Customer perspective e-kanban portal enables your external suppliers, customers or colleagues from another company site to access all relevant Kanban data in real time via internet. This system transits Kanban signals in email delivery of Kanban cards or through e-Kanban online Access. This system provides the following advantages:

- visualization in real time,
- visualization of Kanbans which need to be replenished within the loop,
- optional printing and scanning of Kanban cards at supplier side and entering of the messages,
- e-Kanban Board for dynamically controlling the replenishment process,
- early Warning System for timely detection of material shortages.

From Production / Stock perspective this system includes an electronic Kanban Board or also called Heijunka Board. This innovative Kanban Board can visualize Kanban cards on the screen and in combination with an appropriate solution, highly efficient pull processes can be established in the production area. The advantages of the electronic Kanban Boards are:

- no manual Kanban Boards anymore and thus elimination of falsely inserted cards,
- simultaneous control of hundreds of Kanban control loops possible,
- automatic and dynamic prioritization of Kanban orders,
- quick overview of complete Kanban situation,
- an optional Heijunka sequence visualization of Kanban loops,
- the innovative web-based e-Kanban Board can also be applied by external suppliers, customers and logistics centers.

Therefore the e-Kanban system uses three modules, to monitor the system continuously, to optimize it and to adapt it. [3]

Early Warning System allows the timely detection of possible material shortages to avoid missing parts. This system rapidly detects of potential materials shortages, controls and detects delayed delivered Kanbans and provides of useful information for the supplier. [4]

Kanban Analyzer allows a selective and continuous analysis and optimization of the Kanban system and monitoring of the key performance indicators.
Demand Manager enables the fast and easy re-calculation of the Kanban levels for many Kanban loops and secondly, the Kanban card handling will be self-regulated in the IKS system automatically. It uses newly loaded requirements lists, historical requirements or a mix of new and historical requirements. [4]
In the future, multidimensional representation of all delivery streams based on the Kanban pull principle between different plants will be possible. Ultimately, an e-Kanban multisite CLOUD is growing.

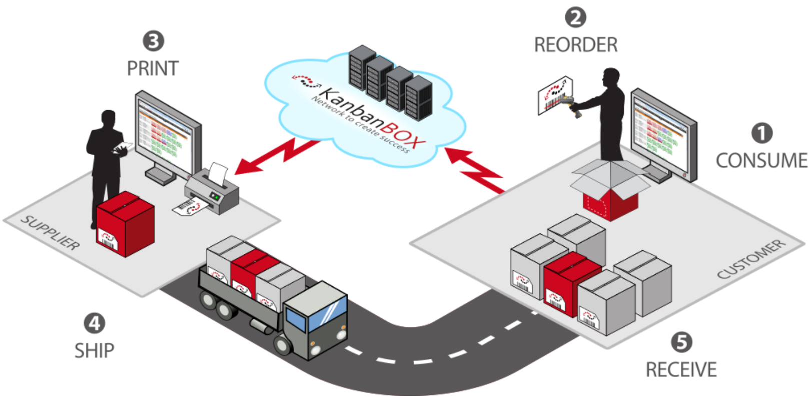

Fig. 1. E-Kanban solution

3. INDUSTRIAL RFID SUPPORTS KANBAN SYSTEM

RFID is the ideal tool to enhance conveyor and material handling systems. Bins equipped with small RFID tags and read/ write heads are mounted on to the shelf and they are connected to a suitable controller that interfaces with the plant's ERP system. As a bin slides down, its data is accessed and verified, making sure that the proper parts are being used at the assembly location.

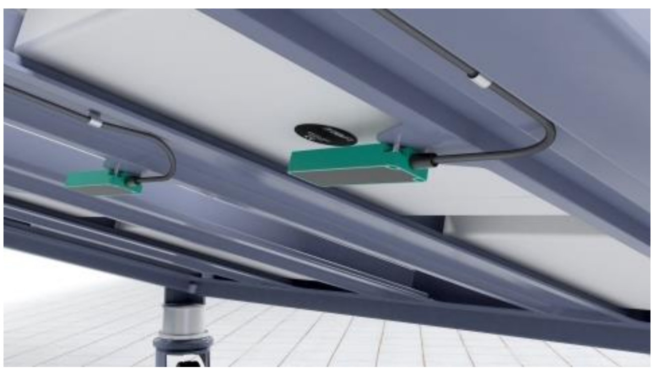

Fig. 2. Using an RFID tag

This type of setup can remove an empty bin and a parts order is automatically triggered at the warehouse. Some users go even a step further by combining the visibility of data afforded by an RFID solution with a pick-to-light system, thus guiding the operators to the bin containing the item needed next. [5]
The modern "push" based manufacturing concept with a Kanban system simplifies demand forecasting, as all necessary parts are refilled automatically. Small and flexible assembly units are formed. Combined with suitable assembly instructions, they produce products of highest quality without any additional raw material disposition.
The goal is highly efficient manufacturing of products composed of a number of parts and components that can be assembled into a large number of product variants. Customer advantage is that the necessary parts are always available line-site; manual ordering processes are not required. The association between bins and parts is automatic and free of errors. [5]
Benefits at a glance of this system are:

- the thin RFID read/write head is easily integrated in Kanban shelf systems,
- ensuring material availability at the material refill locations reduces the risk of costly system downtime,
- Just-in-time order initiation optimizes on-hand stock.

4. CONCLUSION

E-Kanban system ensures that all information is available in real time and online. This system requires low department effort and minimal maintenance costs. All Kanban signals are sent in real time and are visible on the screen immediately. Optimal control and monitoring of all Kanban information is in real time. Continuous improvement of inventory levels and delivery lead-times is based on historical data. Adjustment of Kanban levels is based on changing demand. Thus a considerable potential is available for further optimizations.

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Shopfloor, Management, Lean, Implementation

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IMPLEMENTATION OF SHOPFLOOR MANAGEMENT

Abstract

This article discusses the process of effective Shop Floor Management setting on a shop floor level. Shop Floor Management is a shop floor tool offering effective communication, visualisation of indicators, overview of every work shift, and systematic solutions to problems. The article focuses on facilitating understanding of Shop Floor Management, visualisation, means of systematic solutions to problems, and implementation and use of Shop Floor Management in practice.

1. INTRODUCTION

Shop Floor Management (SFM) is a tool for implementation of our visions and long-term plans. The vision can be achieved by meeting everyday partial goals throughout the whole establishment.

The question about why implement Shop Floor Management is best captured with a quotation of Saint Antoine De Exupéry: „*If you want to build a ship, don't drum up people to collect wood and don't assign them tasks and work, but rather teach them to long for the endless immensity of the sea.*"

SFM is gradually implemented in automotive and other branches of manufacturing industry. However, its implementation brings many objections and queries. Those usually relates to practical usage. Shop Floor Management is often implemented by employees and the own implementation is performed outside the terms of their other duties. They "encounter" many tasks, while their solution may differ from the prescribed standard

1.1. Comparison with the classic method of management

The classic management method is described as authoritative, focused on results, giving and inspecting tasks.

In comparison to that, Shop Floor Management is described as management performed at a place where values are created – at the workplace. The principle is to ask questions, listen to answers, and then, by means of an experienced mentor or moderator of Shop Floor Management meeting, systematically search for causes of problems and remove them. Unlike

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the classic management method, this process is formed by those using it. Decisions are made based on data and facts from the workplace

1.2. Elements of Shop Floor Management:

Characteristic features:

1) Visualisation: Minimal obstacles in the flow of material and information. No problem should remain hidden. If "everything is OK", it may indicate an inability to see problems. And that alone is a problem.
2) GEMBA - Going to the workplace: Regular revision of fulfilling of the plan / workplace requirements. The management should not believe that it is possible to control the processes from an office.
3) Solving problems: Let the people responsible for the process to solve the problem. Remove obstacles that prevent people from effectively solving problems with processes, for which they are responsible. If YOU are the one solving the problem (top management), the potential of your people is not developing.
4) Eveloping abilities of people: Ability to teach people to see what the management sees. Teach people to see problems even in your absence, so that the people want to solve the problems. [1]

Shop Floor Management usually has four structures of meeting:

1) The first level of Shop Floor Management is right at the production line. Task of this level is to evaluate the development of previous shift within 3 to 5 minutes by means of statement of productivity, quality, OSH (Occupational Safety and Health), and eventual problems with machines and quality. Also, a process of the shift may be evaluated by hour stability of performance.
2) The second level of Shop Floor Management is foreman-level management performed by the foreman or the appointed partners. The level focuses on effective sharing of information, quick and systematic solutions to problems. The meeting takes approximately 15 minutes. In case a problem is not solved, it is escalated to higher levels.
3) Level three is the level of Production Managers. (If a company is considered to be a medium-sized or large manufacturing plant, it usually has more Production Managers according to individual technological operations.) The meeting is moderated by a moderator according to set rules for Shop Floor Management meeting including evaluation of defined indicators, problems solution, and eventual escalation to higher levels.
4) The fourth level is the directorship level. Here, the trend of defined indicators is being assessed and eventual deviations are being reacted to. [3]

Each level has its own set rules for communication, duration, list of participants, and eventual escalation procedure. [1, 2]

2. THE SUGGESTED SOLUTION PROCESS

The process below was designed for implementation of Shop Floor Management in a Czech manufacturing company with several plants in the Czech Republic.

1) **Define the objects for management – processes:** In this step, it is important to determine the processes, their interfaces, define what processes will have their own Shop Floor Management meeting. Determine, based on size of the whole operation, if it is necessary to have all four levels of Shop Floor Management or if it is possible to merge

some of them, reducing the number of Shop Floor Management to 2 or 3 levels. Find out if the given manufacturing area offers a suitable place for a Shop Floor Management information board.

2) **Set teamwork – set a team:** A team must be created for each level as well as a team leader. This team will participate on Shop Floor Management meetings. Each team and its participants have their important roles within the scope of the team. One of the important roles is a meeting moderator.
3) **Description of the process – indicators:** Before the Shop Floor Management is implemented, it is necessary to define indicators describing the manufacturing process and split them to individual partial levels.
4) **Set of goal – I define what's right and what's wrong – standard:** In general, we know management by missions, visions, goals, and priorities. In Shop Floor Management, that is "projected" to all levels of management. The point is to determine indicators per given production process that would describe performance, fulfilment of delivery, quality, etc. Ultimately, those are process indicators that affect financial management of the company and satisfaction of a customer. If we have a set goal, we define the manner and frequency of observing fulfilment of the goal (goals), determine the reaction to a deviation from the goal, and eventual escalation procedure.
5) **Standard visualisation – clear identification of deviation:** Although we are in 21st Century and in times of Industry 4.0 being implemented and we often have our data shown on a screen (offering visualisation right in the area of operations), Shop Floor Management focuses on writing down the indicators manually. Manual filling up of a graph brings awareness of the leaders regarding the current state and trend. Additionally, visualisation of an action plan and state of fulfilment of tasks in the action plan including deadlines and responsibilities are a part of the visualisation.
6) **Regular communication – communication calendar:** Effectiveness of Shop Floor Management meetings lies in their regularity. For that reason, a communication calendar must be created. Also, the practical part of implementation showed that communication calendar is important if a given responsible leader is to participate on more than one meeting that may be held at the same time.
7) **Problem solving in place of their occurrence in Gemba:** Gemba is a Japanese word for a place where a value is being added. Which is in manufacturing. Systematic solution of problems and identification of their causes may be effectively influenced when working with real data directly at the place of their creation and with people working on the given product.
8) **Problem solving – standard process of finding a root cause:** For example, a root cause may be searched for by means of Ishikawa Diagram (fish-bone diagram) or by a "5 times why" method. When searching for causes, it is important to have a multi-professional team of people working in the given process, since together, they are able to affect the process.
9) **Sustainment and discipline – leadership standard, escalation plan:** Besides implementation, sustainability is a very important element of Shop Floor Management and depends on discipline of individual participants. User training and description of escalation procedure and leadership are an important part of sustainability.

3. CONCLUSION

Shop Floor Management is a powerful and effective tool for management in all levels of manufacturing. Despite some objections of implementers and participants of the implementation procedure, Shop Floor Management is a suitable tool for manufacturing companies. The procedure described above is verified by Czech practice. The most significant problems during implementation are to find a suitable method of visualisation, coaching, and moderator training in order to keep within the rules for communication and subject, ability of the leadership and "involvement" of operators in the lower parts of problem solutions.
A significant advantage of Shop Floor Management is an open communication above the real indicators arising from manufacturing, immediate feedback from the process, problem solving in real time and with people that are a part of manufacturing processes.

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Mixers selection, Process of designing mixers, Modeling of mixing processes

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SELECTED PROBLEMS OF MIXERS CONSTRUCTIONS FROM THE VIEWPOINT OF THEIR RANGE OF APPLICATION

Abstract

In this work an exemplary construction of mixers are presented. The determining question of the mixer construction is described from the viewpoint of media type, execution costs and effects of exploitation. This work gives rules about structuring of knowledge base for selecting mixers by marketing service of the producer.

1. INTRODUCTION

In the last years the demand of mixing devices for different media types (liquid, gas) in the economy is growing. For example in the chemical or food industry, the wastewater treatment. Different solutions for construction of this devices appeared on the market. Example of mixer is shown on Fig. 1.

Fig. 1. Example of mixer construction [1, 2]

Mixers for blending the same media type can have different construction solutions. Individual parts could be made from different materials and various manufacturing technologies. It affects

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to the various costs of manufacturing and various efficiency of operation, i.e. blending time, lifetime, maintenance costs etc. Selection of mixers depends on requests and financial possibilities of the customer and capabilities of the producer. In order to be competitive on the market, the producers reduce the production costs. Helpful is here “Target Costs”. Furthermore, at the manufacturing stage, “Kaizen Costing” can be used to tuning the process of unification of the single parts, rationalization of the machining and assembly costs.

2. DESIGN ARRANGEMENTS, PROBLEM OF MIXERS SELECTION

In the example tank with a central build mixer, it could be happened a central funnel, especially in case of turbulent flows. This phenomenon can be eliminated by using baffles. An important aspect is also the occurrence of „dead” zones in the tank, areas where the media is not mixed. The problem of blending, which affect the mixer construction, can be solved by using *Computational Fluid Dynamics* (CFD). In this work we have used ANSYS Fluent to CFD simulation. The tank with a diameter of 1.5 m and a cylindrical bottom (0.45 m high) was designed. The working capacity of the tank was about 4 m^3 and the liquid level was 2.25 m. In the tank were placed two baffles parallel to each other to prevent that a funnel will originate. They are designed equally spaced from the tank wall, with a gap of 0.04 m. Inside of the tank there is a central located shaft and impellers on it. On the beginning there were designed two steel impellers. After that the system was modified – a third impeller was added between the existing impellers. The position of each impellers on the shaft was changed. Assumptions regarding of the media and the impellers have been made. The medium has a density of 1070 kg/m^3 and a viscosity of 0.04 kg/m*s. The diameters of the impellers were selected in according of the tank diameter. In each cases it was 0.65 m. The rotation speed was set on 120 rpm. The impellers can have different numbers of blades, e.g. 3 - blade - impeller, 8 - blade - impeller. During designing of the mixer there were used the technology solutions of REDOR Sp. z o. o. The variants of the different mixers which have place in the research are shown in Fig. 2., illustrating the interior of the tank with baffles.

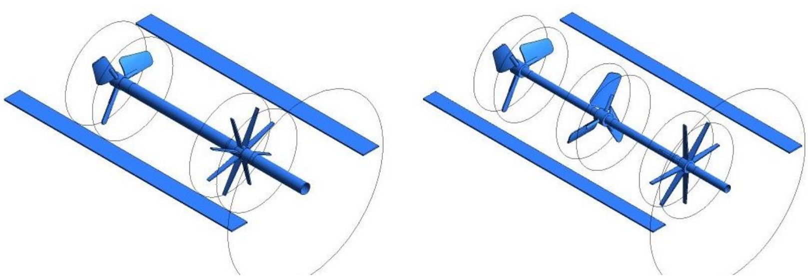

Fig. 2. Variants of mixers: with two impellers (on the left) and tree impellers (on the right) [3]

3. MIXING PROCESSES - SIMULATION

Simulations were carried out for different mixing variants (number of impeller blades, their type and their location) in a steady state. Simulation have been carried out to determine the presence of funnels and “dead” zones in the tank for selected variants. In order to illustrate the turbulence was used a two equation *k-ε* model, composed of the turbulence kinetic energy equation and turbulence energy dissipation equation, supplemented with empirical coefficients

(constants). Solving the problem is combined with the mass conservation equation and momentum conservation equation.
Mixing power obtained from simulation in the first variant was 1,52 kW, while in the second 1,35 kW. It was calculated according to the equation obtained from the transformation of torque formula (equation 1).

$$P = \frac{M \cdot \eta}{9{,}55}, \tag{1}$$

where: P – electric power of mixing [W], M – sum of torques [Nm], η – rotational speed [rpm].

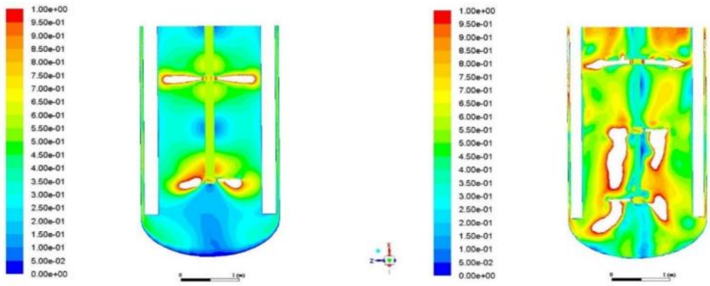

Fig. 3. Contour plots of velocity magnitude [0-1m/s] (xz plane) [4]

4. MANUFACTURING PROCESS OF MIXERS

The manufacturing process of mixers is shown on Fig. 4. The process consists of assembly of the unified, commercial and internally produced components. From the manufacturing cost perspective, the mixers should consist of as much as possible unified and commercial components. Workpieces should be manufactured in according to rules of group production. The organisation of the production influence on the manufacturing costs. The production cycle can be reduced when a part of the components is stored in semi-finished warehouses.

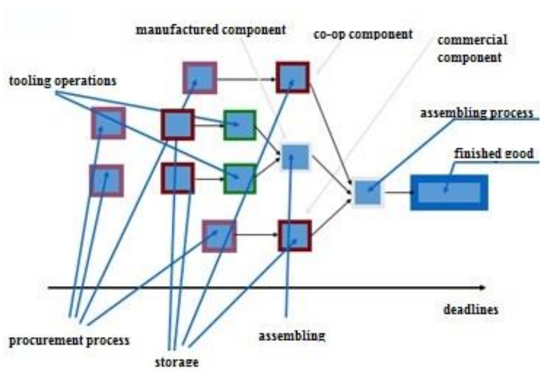

Fig. 4. Mixer production process [own study]

The efficiency of mixing depends on mixing construction. The costs increase in case of more complex design. The problem from the viewpoint of investment possibilities of the customer can be solved by ”Pareto Optimum”, in according to Fig. 5.

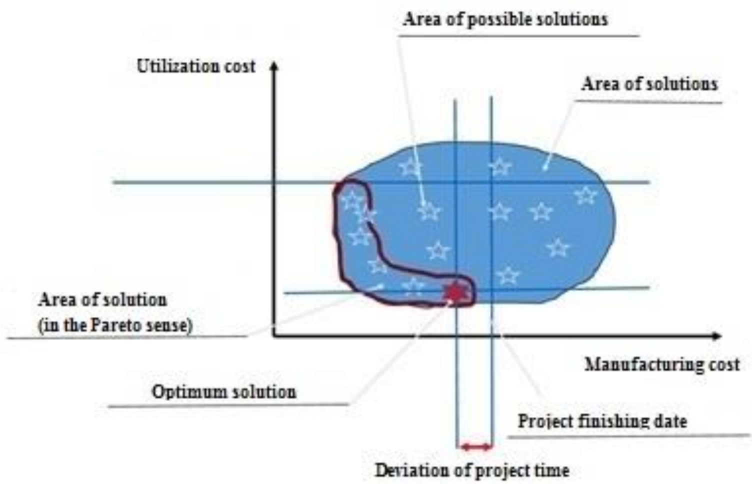

Fig. 5. Solving the problem of mixer selection (optimum in the sense of Pareto) [own study]

5. SUMMARY

Presented on Fig. 3. the contour plots of velocity magnitude in the tank indicate much more efficient mixing by variant 2 with three impellers. “Dead” zones are shown in variant 1 - areas between the impellers and on the bottom of the tank, where the medium flow is near zero (dark blue areas). Existence of two baffles prevents that a central funnel originate. The difference in the calculated mixing power values are over 10%. Electrical power consumption is higher when two impellers are used for medium blending. More effective solution allowing blending without “dead” zones, central funnel and be more economical is to use a mixer with three impellers.

Operation costs consist of service costs which are depending for example of the different materials of the blades or the complexity of the construction design.

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DFX Method, DFA Method, DFM Method

Michala ŠELIGOVÁ*, Ľuboslav DULINA**, Miroslava KRAMÁROVÁ***

ACHIEVING THE REQUIRED RESULTS IN THE FIELD OF ASSEMBLY AND MANUFACTURABILITY USING THE DFX METHOD

Abstract

Shortening the life cycle and increasing the number of types of products' variants represent some of the main aspects of the current market development. An ideal approach to improvement of life cycle of products can be found in the DFX methods. Additionally, the right implementation of these methods can, except for the reduction of the time and costs, improve the quality of products and their design as well.

1. THE DFX METHOD

The DFX (Design for Excellence) is a method providing an integrated framework and guidance for activities that consider the product's design and the costs of value chain and marketing affecting the product and industrial process design. This enables organizations to create an accurate product portfolio needed, by the reduction of current diversity of components. It also brings an optimal choice in the overall fulfilment of the chain. [1]

The DFX term is interpreted as the design for excellent results, probably because there is "X" variable in the concept itself, which can be substituted with conditions from the set of expressions being considered in the design, and it can lead to excellence in the field of mechanical engineering and business. This set of conditions in not limited only by the words as quality, price, modularity, interchangeability, reliability, logistics, procurement, Six Sigma, manufacture, assembly, removal, obsolescence, operability tests, or preservation of the environment. These conditions share the fact that they belong into some of the phases of the product life cycle.

The product life cycle, according to the oldest terms, can be divided into the phase of development, manufacture, using and removal. Each of these phases is affected by the DFX

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method somehow [3]. Thus, the DFX refers to the use of formal methodology for optimization of a particular aspect of the design. The X variable represents three main fields of focus:

- Design for Manufacture / Delivery,
- Design for Evolution,
- Design for Operation,

Each of these fields includes other methods from the DFX range. By their implementation it is possible to achieve the reduction of product's total price, improvement of the market position or enhancement of competitiveness. The aim of implementation of the DFX method's tools is also the increase in efficiency of the assembly process of the selected product or of some of its subsets. To meet these requirements, the most suitable way is to use the combination of the DFA and DFM method.

2. THE DFA METHOD

The most common practice in this method is to reduce the number of parts in the set, which leads to the reduction of provided activities, thus the manufacturing or purchasing activity, to the shortening of assembly time, manufacture time, and to the reduction of manufacturing costs. It also focuses on assembly operations that are the part of product life cycle. The DFA considers 5 – 9 factors related to the specific product, such as the symmetry of components, their size, weight, placing, orientation, shape properties, and other. It also includes 5 – 9 primary factors related to the assembly process, such as inserting, handling, fixing, orientation, and special tools and agents. Answering and assessing these questions lead to better design engineering decisions with regard to easier assembly. At the same time, a suitable environment for the team work is being created, so the efficiency of assembly is being improved as well.

In principle, the DFA admits that it is necessary to analyse the design of all parts of a product for all the problems with assembly already at early phase of the process, and to reduce the costs throughout the product cycle this way [2].

The right implementation of the DFA method will fulfil the following criteria:

- reduction and optimization of the number of various types of components,
- use of optimal methods of assembly,
- utilization of the gravity in the work,
- minimization of orientation changes of components during assembly,
- provision of easy access and unlimited view,
- provision of easy and safe handling of individual parts and sets,
- creation of components that can only be installed correctly,
- minimization of the number of tools needed in the assembly process.

The design of assembly strives for simplification of the manufacture by reducing the costs of assembly. Consequently, application of the DFA principles usually brings the improvement of quality and reliability, and reduction of manufacturing facilities and of a part of inventory. It was repeatedly found out that these secondary benefits often exceed the reduction of costs in the set.

3. THE DFM METHOD

The DFM tool – Design for manufacturability is one of the DFX tools. The DFM is suitable for early assessment of manufacturing issues already at the stage of product development. It shortens the product development and delivery times by facilitation of communication among design engineers, process planners, quality specialists, purchasing officers, suppliers and any other parties involved in the product development.

The DFM tool reduces the costs of the product development as well as the manufacturing costs, e.g. by minimizing the design changes, by interchangeability of parts, and by the availability of materials and standard components. Prerequisite for provision of this process consists of good knowledge of individual manufacturing processes and of realistic consideration of the limits of supply and manufacturing chain.

To facilitate achievement of these aspects, it is suitable to observe some principles:

- **Simplicity** – a product with a low number of simple parts and short production sequence will be cost-effective. Such product also has simple service. Thus, complicated, disorganised and unclear shapes should not be used.
- **Standard materials and components** – from the production perspective, it is convenient to use materials and components with a broad use, and standard semi-finished products with short delivery times.
- **Standardized concept of product's design** – in the case when several types of products are being produced and it is convenient to use the same components in the product design for various product type series, it can save the costs of measurement and testing of parts in the production.
- **Free tolerance** – it is the name for dimensions without strict tolerances. But even these must be produced within the tolerance of the corresponding standard. The higher the accuracy of the part's dimension stated in the design, the higher the cost in the production.

4. THE DFMA METHOD

By combining the tolls of the DFA and DFM, the DFMA tool (Design for manufacturability and assembly) was created. The DFMA also belongs into the "family" of Design for "X" tools. It is described as a systematic procedure with the aim of helping the firm to fully use the existing production processes, and to minimize the number of parts for assembly. This approach leads to simpler and more reliable products whose manufacture and assembly is cheaper, and each reduction of the number of parts generates a multiplicative effect in the cost reduction, because there are no other designs and specifications needed, and the sub-supplies together with inventory levels decrease as well. All these factors have a significant influence on the overhead costs, which represents the biggest part of total production costs [4]. It is not a design engineering system, but as every innovation, it must be based on the design engineering team, and it must enable the quantitative assessment as a support in the decision making during the initial phases of designing. This tool also supports communication among design engineers, production and others involved in the generation of the total production costs during initial design engineering phases. The process of the DFMA method implementation:

- **Gather information for the DFM** – drafts, designs, product specifications, design alternatives, detailed comprehension of the production and assembly processes, estimations of production costs, of production volume, …
- **Define production costs** – reduce the costs of components, assembly, production support, consider the effect of the DFM decision on other factors. Make sum of all expenditures on the system inputs (i.e. components being purchased, energy, materials, etc.) and on disposal of waste produced in the system.

- **Understand links of individual processes** – close cooperation with design engineers (awareness of complex operations with high costs), redesign of expensive parts with the same purpose while maintaining the level of production costs.
- **Eliminate superfluous steps** (in the production process), alternatively use substitutional steps.
- **Chose an appropriate economic scale** – increasing the production volume usually reduces the production costs.
- **Standardize components and processes** – components common for more than one product, analysis of tools (clustering of identical technologies).
- **Reduce the costs of assembly and production support** – the DFA index, increase the facilitation of assembly, predict possible types of failures, take suitable corrective measures already at early stages.
- **Consider the influence of the DFM implementation on other factors** – product quality, costs, time, repetitive components.
- **New cases** – production approaches, Just-in-Time, …

5. CONCLUSION

In industry, the quality and reliability of any product depend on the ability of the producer to produce the product correctly, whether it is the case of own production or production to order from a sub-supplier. Production problems represent one of the main reasons why many firms cannot meet their obligations, which causes them considerable financial losses, and consequently the mistrust of market. High number of engineers and managers surprisingly focus their attention on the production process, even though it is just one reason of a potential failure – product development and design also have a considerable impact on the product quality. Therefore, it is appropriate to use not just one, but a combination of at least two DFX methods, and to observe the rules, principles and recommendations during their implementation and subsequent use.

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DFX Method, DFA Method, DFM Method

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IMPLEMENTATION OF THE DFX METHODS

Abstract

The DFX term has various meanings for various people. These differences reflect the position of an individual in an organization and his attitude to it. Naturally, individual opinions are based on previous experience with the use of the DFX methods, which can be good or bad.

1. DFX METHODS

The DFX (Design for Excellence) creates a philosophy and a proved procedure that supports communication and collaboration among design engineers and production departments responsible for the design and production of final products.
What value does it bring?

- it provides a continuous process of design and feedback,
- is mitigates the exceeding of project costs,
- it shortens the time of market launch,
- it enhances product's performance and its reliability,
- it reduces the total costs.

1.1 Implementation of DFX methods

To implement the DFX philosophy with the highest efficiency possible, certain systematic procedures should be observed, which are easy to use. It is also useful to use work forms (sheets) displaying the data in a logic manner together with an easily accessible knowledge base.
By harmonizing these three aspects, it is possible to work with the product or process data based on the DFX method according to following steps [1]:

- **Product analysis** – the main objective is to gather and clarify information pertaining to the product. Each DFX tool usually determines what product data it needs to know, and how they shall be processed and presented. More detailed product data can be required and collected in later steps.

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- **Process analysis** – it is mainly connected with the collection, processing and presentation of data on the process. As well as the product information, the pieces of process information are either input for the following steps, or they represent one of the outputs of DFX tools.
- **Performance measurement** – as soon as the analyst has the product and process information at his disposal, interactions are being detected in the form of corresponding performance indicators accordingly to the specific DFX tool. It can require further data collection and information processing.
- **Emphasizing through benchmarking** – by benchmarking, the focus is on the determination of performance standards and on the comparing of performance indicators with these standards. After calculating their values, it is possible to directly perform their assessment and presentation of results.
- **Diagnosing for improvement** – the previous step makes it possible to find out what is good and what is not. To solve the problem, it is necessary to know its cause. It needs to be revealed why some areas are weak or strong. Many DFX tools deal with it.
- **Recommendation of changes** – this step mainly concerns the examination of the highest number of potential improvement in the specific area. Each DFX tool offers advice for the change of design, but most of them leaves the responsibility to the analyst or team. They also provide a way of minimizing the number of parts.
- **Setting the priorities** – the DFX analysis can reveal the causes of problems and their alternative solutions. Thus, the aim of this step is to set the areas of vital importance for further examination, and to solve immediate trivial issues, so that the attention can be focused on important problems and promising solutions.

So, the DFX pertain to the use of formal methodology for optimization of a certain aspect in the design.

1.2 When to implement the DFX method?

Implementation of these methods is not time-limited. DFX methods can be implemented in any phase of product life cycle. However, speaking of the costs during product life cycle, these are lowest during product development. Therefore, it is the most suitable to implement the DFX method just in this area. The responsibility of the amount of these costs works reversely, thus it is the highest there. Of course, this method can also be implemented in other areas (purchase, manufacture), but the costs are rather increased here [2].

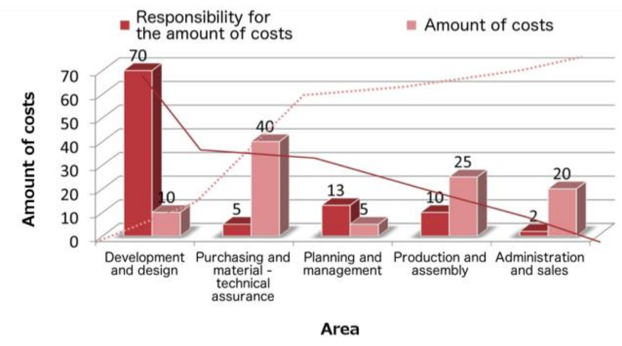

Fig. 1. The amount of costs during individual stages of product life cycle

Other costs of failure removal relate to it as well. Whilst during the development phase failures can be prevented or removed at lower costs, this is more difficult during the production phase. Naturally, revealing the failures in testing or even by customer is the most expensive.

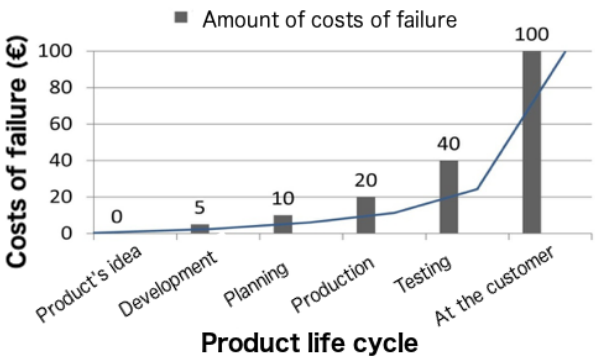

Fig. 2. Costs of failure removal during the product life cycle

Therefore, it is the most favourable to implement DFX methods immediately at the stage product’s idea and no later than at its development.

2. SOFTWARE SUPPORT

The selection of appropriate software contributes significantly to the achievement of required results as well. Nowadays, there is a wide range of software solutions on the market for the analysis using DFA/DFM (DFMA) methods. An example is represented by the software of the *Boothroyd Dewhurst, Inc.* from the USA. This company offers software support for DFM, and subsequently for DFMA method (Fig. 3.). The DFM software can suggest alternative materials, and using the DFMA it is possible to relatively accurately estimate the costs of individual components of assembly units, assembly time, or to provide the design of alternative assembly operation.

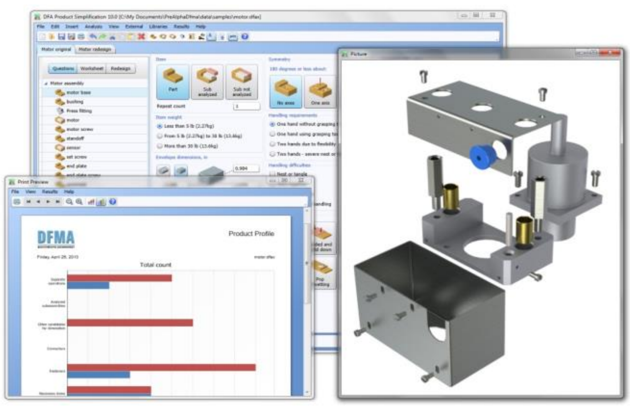

Fig. 3. Boothroyd Dewhurst company’s software [3]

Using the software support can considerably facilitate, speed up and increase the efficiency of processing of not only product analysis, but also of process analysis, and of the suggesting of potential corrective measures.

3. TEAM WORK

The results of various studies revealed that up to 80% of production costs of a new product arise already at the phase of first product drafts where the responsibility lies mainly on the design engineer. But it is also influenced by the way of production of individual parts from the perspective of technology used, machines, tools, agents, gauges, semi-finished products, standardized components, etc. Additionally, it is also necessary to establish simpler and faster assembly of products at lower costs.
However, this places high demands on an individual (design engineer), therefore teams are often used in the product development, consisting of design engineers, technologists, process planners, purchasers, suppliers and any other parties involved in the product development. The solution is based on the creation of a multifunctional mixed team. An integration of knowledge of individual specialists is valuable, because the feedbacks from the perspective of various aspects of the product's manufacture are considered already in early design drafts of a component.

4. CONCLUSION

Many companies have realised that in order to catch up with the producers of the Far East (and now also of the West), it is necessary to use new tools and techniques. Design for Excellence is a philosophy that supports fast and successful product through the support of communication and collaboration among departments responsible for the product design and production. Implementation of a successful DFX programme will shorten the time of product development, reduce production costs, shorten production cycle, and at the same time it will increase product's quality, reliability, and eventually the most important aspect – it will increase customer's satisfaction.

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Reconfigurable Manufacturing System (RMS), Reconfigurability, Factory of the Future

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SATISFACTION OF CUSTOMER REQUIREMENTS USING RMS

Abstract

The article provides an overview of market´s current situation, which describes customers' requirements. To meet these requirements, there is a need for basic strategies specified by production paradigms that are also stated in the article. Next part is devoted mainly to RMS systems and some key parts of RMS are described. Conclusion contains the suggestions for further examination on the area of RMS.

1. INTRODUCTION

In order to understand the direction and development of new generation of production systems it is necessary to understand the deficiencies of current production systems. Production systems change these days especially in faster introduction of a new product to the market, where new versions of consumer and computing technology, cars and other devices are on fast increase. The main reason is increasingly demanding customer, who requires highly customized products [1]. Companies are then forced to expand their production portfolio, to shorten the lead time, and to handle rapidly-changing demand more effectively. These requirements considerably influence performance of the production system, so to meet them, it is necessary to determine a basic strategies.

1.1. Strategies to reduce lead-time

Product lead-time has been generally defined as the time needed to meet a customer's order. It can be reduced in three different ways: by reduction and elimination of indirect activities such as transferring and buffering, by increasing of production capacities, and by parallelism of more production departments.

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1.2. Strategies to increase product variants

As each product has been assembled from the set of basic parts, production variability consists of distinction in making of components or different assemblies of the basic parts. Increasing of product variants can be reached by optimization of product platform and by increased variability and versatility of assembly and manufacturing resources.

1.3. Strategies to satisfy fluctuating demand

Product platform is a set of basic components which are related and enable effective development and manufacture of the product. Well-planned product platform may considerably reduce system's susceptibility to change on product volume.

1.4. Strategies to reduce the cost

The ways in which activities and resources are organized considerably influences the costs and also the final product price. Costs-reduction is realized via elimination of both indirect and direct activities, waste removal, of increasing efficiency and overlapping the subsequent activities.

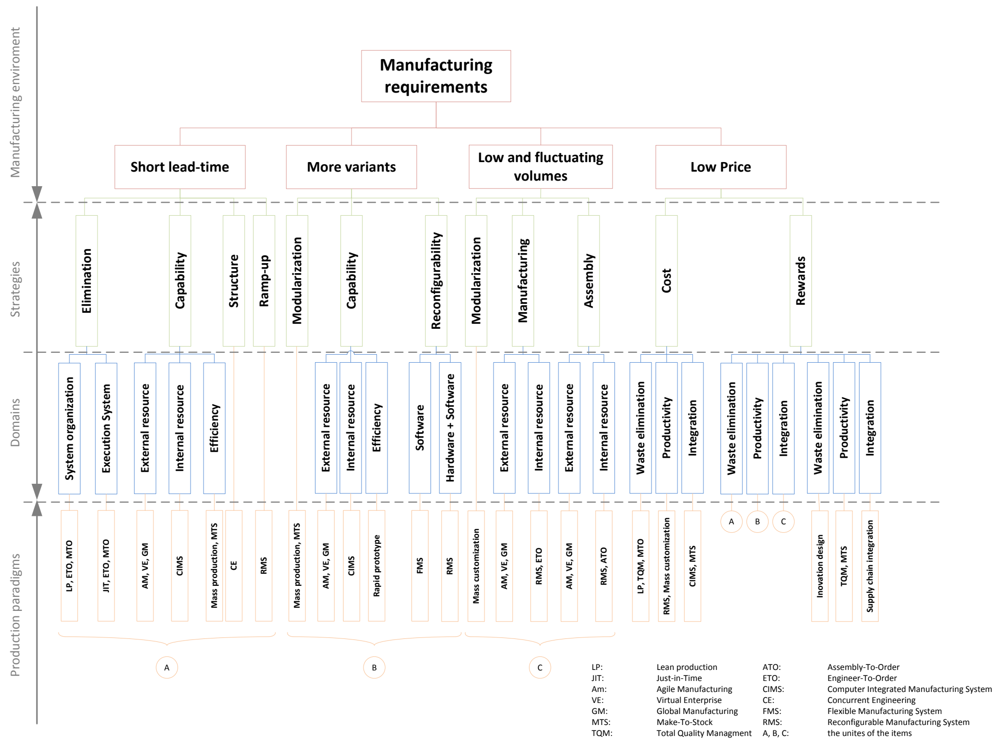

Fig. 1. The Division of Production Paradigms

1.5. Taxonomy of production paradigms

The Fig. 1. provides taxonomy of production paradigms. It consists of four layers. At the first layer, four key manufacturing requirements are listed. The second layer contains the strategies for meeting above mentioned requirements. The third layer illustrates the domains of a manufacturing system where the strategies are applied. At the fourth layer, various production paradigms are classified in terms of the applied strategies and domains. Some paradigms, such as Reconfigurable Manufacturing System and Lean Production, can meet the requirements in different ways since their implementations fit into different strategies. Moreover, it is very difficult to tell that one paradigm is better than another without the consideration of the unique situation of a specific enterprise. All of these production paradigms have their strategies to meet the specific requirements in one way or another [1].

2. CONCEPT AND DESIGN OF RMS

As it was shown in the Fig. 1., RMS is one of the most effective paradigms used to satisfy future manufacturing requirements. In general RMS is defined as the system with the ability to reconfigure hardware and control resources at all of the functional and organizational levels, in order to quickly adjust production capacity and functionality in response to sudden changes in the market or in regulatory requirements (e.g. turbulences). RMS system's design is usually divided into three parts: architecture design, configuration design, and control design. Architecture design determines particular parts of systems and their mutual interaction. RMS architecture contains basic key characteristic, such as modularity, scalability, integrability, convertibility, and diagnosability. The design of architecture includes also hardware and software design for future systems (see Fig. 2.). The hardware system includes reconfigurable machining systems, reconfigurable fixturing systems, reconfigurable assembly systems and reconfigurable material-handling systems. Configuration design is based on an assembly of the selected modules whereas this configuration can optimally fulfil the given task [2, 3].

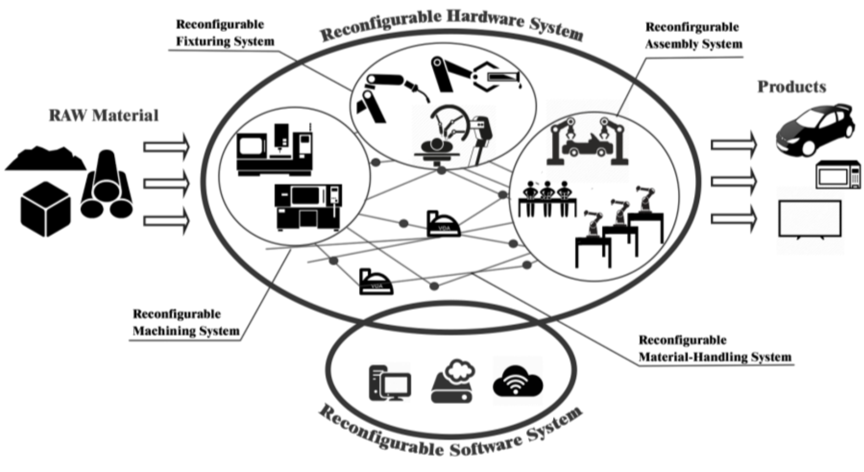

Fig. 2. Design of RMS Architecture

Configuration design can be formulated as an optimization problem. In design-creating task it is necessary to define constraints derived from task specifications and related variables, including modules types and their count. Configuration design is involved at the phase of the system application. Last part applied in the system operation is control design that should meet following requirements [3, 4]:

- The control system should be autonomous since a system level objective is decomposed into module level objectives. The control system should be also capable to integrate and coordinate the modules to implement system-level objective.
- The control system should be distributed and modularized.
- The control system should be open so that it can update controlling components.
- The control system should be scalable and upgradeable.
- The control system should be self-reconfigured.
- The control system should be able to identify the changes of task specifications.

3. CONCLUSIONS

RMS paradigm is one of the most effective ways to solve problems related to demanding customer requirements, fluctuating demand, and globalized markets. These systems do not provide a solution for all problems of future generation factories, so they cannot be taken as final solutions. In the present time there exist only few solutions dealing with combination of more productions paradigms for future systems. For example, the concept of Lean Production (LP) could be a supplement to an RMS, so that an enterprise can apply RMS to optimize the utilization of the portion of resources for specific product families, and it can also reduce the waste caused by the portion of the idle resources of an RMS. Further part focuses on creation of control system which should be autonomous, distributed, self-reconfigurable and scalable. Open Architecture Control provides the infrastructure to implement RMS control, and the agent-based technologies meet most of these requirements.

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Ergonomics, Expert system, Work-related musculo-skeletal disorders

Richard WOROBEL*, Peter BUBENÍK**

APPLICATION of ergonomic expert system FOR ASSESMENT and REDUCTION RISK OF WORK-RELATED MUSCULO-SKELETAL DISORDERs IN REAL CONDITIONS

Abstract

The article describes the practical use of an ergonomic expert system for assessment and reduction risk of work-related musculo-skeletal disorders (WRMSDs), in different job positions in company. Within the article, the current situation in the field of application of ergonomic experts systems is presented, followed by presentation of application of ergonomic expert system in real conditions.

1. CURRENT SITUATION IN THE FIELD OF APPLICATION OF ERGONOMIC EXPERTS SYSTEMS

Constant increasing of efficiency in manufacturing companies is a recent trend. So it is necessary to advance and improve the conditions for workers from the perspective of ergonomics, and consequently to reduce possible occurrence of WRMSDs. In Slovakia, the current status of improving ergonomic conditions for workers is inadequate. A large number of companies lack experts, but not only from the ergonomics field. To obtain expertise in the given field is necessary to accumulate information and knowledge, to learn the rules and skills for their proper application in real conditions. This is long-term and expensive process and therefore experts are a limited and scarce resource. For instance, in USA there are overall one hundred million employees and only 5 000 are professionals in the field of ergonomics and barely 2 000 of them are certified. And therefore, for one certified ergonomics expert falls 50 000 employees [1]. Nowadays the companies can solve this shortage in two ways. They can either pay the required expert from consultancy firms for a limited time or train their own employees by a wide range of expert courses. Both of these possibilities are financially demanding, and in case the trained employer leaves the company, the whole training process must begin all over again. In the recent years, there has been development of expert systems, especially in foreign countries, where they are tested under real conditions [2]. These systems can replace the knowledge of experts, at different levels of management and thus help solve

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problems. Nowadays the expert systems are slowly becoming popular in Slovakia, so in next chapter one of the newest expert systems will be described.

2. ERGONOMIC EXPERT SYSTEM-SONEX

SONEX is computer-based ergonomic expert system, which was developed in 2015, to identify ergonomic risks of WRMSDs in different job positions and provide expert prevention advice. SONEX deals with ergonomic work-related deficiencies and worker's subjective difficulties. The aim of the expert system is mainly to propose preventive measures to improve ergonomics in work to prevent these predicted WRMSDs [3]. SONEX forms a rule base and 6 knowledge base modules. The SONEX rule base has over 140 questions, knowledge base includes over 200 risk factors, and around 500 possible answers can be generated [4]. These questions are easy to understand, so anybody (ordinary employees) can answer them. (e.g. Have you ever had any kind of ergonomic evaluation of your working conditions, and the only possible answers are YES and NO). Next parts of expert system SONEX are knowledge base modules (Fig. 1.). These modules are divided into main and supporting modules.
Two main knowledge base modules are for:

- symptoms,
- engaged body part.

These modules are supported by next four modules:

- work environment,
- work chair,
- work tools,
- organization factors.

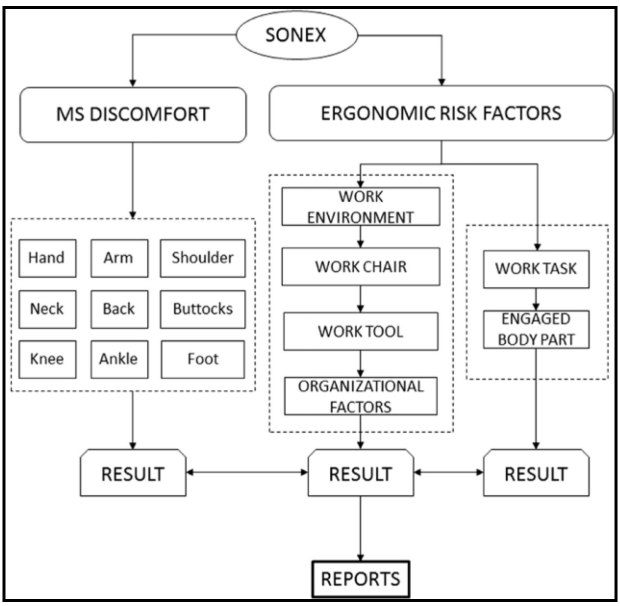

Fig. 1. Structure of SONEX

Interface in SONEX is user-friendly, and can be divided into information and activation part.

Information part consists of:

Project description (basic information about project)
List of employees (list of all tested employees)
Employee description (basic information about tested employees)

Activation part consists of:

Employee part (adding new employees for testing)
Analyses part (starting new analyses for chosen employee)

2.1. Application of ergonomic expert system-SONEX

The system has been tested in multiple businesses for all types of work positions (Tab. 1.), where ergonomic deficiencies and WRMSDs have been known, but during the testing, these shortcomings were confidential. After testing the results from SONEX expert system and another common analytical method were compared. The following standard ergonomic methods were used to validate the software [4]:

- the anthropometric dimensions of the worker and anthrop technical dimensions of their workplace,
- three ergonomic checklists (General Risk Factors Checklist, Office Work Environment Checklist, Manual handling Checklist),
- the OWAS method,
- the workers were observed and interviewed about their job.

Tab. 1. Comparison of software diagnosed injuries with physician diagnoses

ID	**Work place/ employee**	**SONEX result for chosen body part using discomfort module**	**Actual diagnosed condition**	**Agreement**
1	Tailor/female, age 53, works 30 years	**Shoulder:** Neck strain Neck/upper back: Cervical spondylosis	Cervical spondylosis	High Match
2	Mailman/male, age 45, works 24 years	**Shoulder:** Subacromial bursitis Lower back: Lumbar disc herniation	Subacromial bursitis and Lumbar disc herniation	High Match
3	Data entry/female, age 39, works 17 years	**Hand/finger:** Carpal tunnel syndrome	Carpal tunnel syndrome, irregular use of anti-rheumatic drugs due the pain in the neck	High Match
4	Barber/male, age 42, works 18 years,	**Hand/finger**: De Quervain's syndrome Knee: Knee bursitis	De Quervain's syndrome and knee bursitis	High Match

It has been shown that SONEX accurately predicts the risks of possible WRMSDs and correctly identifies ergonomic shortcomings [4]. The main advantages of SONEX over conventional ergonomic analyzes are:

- speed,
- easier to use (no "expert" is required),
- easily expandable.

The results (Tab. 1.) have shown the suitability and benefits that SONEX ergonomic expert system can have after deployment in company. It can efficiently replace the necessary experts for businesses that need to improve ergonomics conditions and reduce the occurrence of WRMSDs.

3. CONCLUSION

Nowadays the issue of increasing efficiency in manufacturing companies gets on a new level. Companies in their effort to increase production and reduce costs, do not take aspect of the ergonomic conditions of employees into view and therefore WRMSDs are becoming commonplace. Solving these problems is often a long-term process in which an expert is needed. As has been proven, experts are scarce and expensive source. Possible replacement for so much needed experts can be expert systems. SONEX expert system for assessment and reduction of WRMSDs described in the article, is a great demonstration how the expert system can fully replace the necessary expert. The results obtained by using the SONEX software have shown its ability to predict, with high accuracy, the WRMSDs associated with different jobs, as well as the correct diagnosis of some of the WRMSDs, on basis of symptoms which employees feel and describe. The software has also identified the ergonomic shortcomings in the work. The software can also compare subjective symptoms with ergonomic shortcomings present in the workplace. This means that SONEX can be used as a diagnostic tool for the ergonomic analysis of the work place, and that the software can be offered to different users as a tool that will enable early detection and prevention of a number of different WRMSDs. Research and implementation of ergonomics expert systems is crucial to increase competitiveness and ensure sustainable development of companies.

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Complex logistics strategy, Model of logistics strategy development, Medium-sized companies

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MODEL OF LOGISTICS STRATEGY DEVELOPMENT IN INDUSTRIAL COMPANY

Abstract

The paper deals with a process of developing the logistics strategy. The first part describes the results of the research realized in Slovak industrial companies of all sizes. The research is focused on current state of logistics strategy creation. The second part of the paper describes the model of logistics strategy development, which was proposed for medium-sized companies.

1. METHODOLOGY AND ANALYSIS OF THE CURRENT STATE

The research with the purpose to analyze the current state of the logistics strategy development in the Slovak industrial enterprises was conducted from the June 2016 to January 2017.
In 2016, the average number of enterprises classified, according to economic activities (SK NACE Rev. 2), as category C – Manufacturing, was 16928. (Average for the period of January to November 2016. Data from the website of statistics.sk, gained 7 January 2017.) Since it is not possible to address the entire population, it is necessary to calculate the size of survey sample, so that the results are correct. Based on putting the data into the calculator of survey sample (Population size = 16928; Margin of error = 10 %; Confidence level = 95 %), it is needed to gain responses of approximately 96 industrial enterprises, if we do not take the size or legal form into account.
So far, 394 enterprises have been addressed, and the questionnaire was completed by 98 of them. So, the response rate is 24,87 %. The final respondents are managerial positions, especially logistic managers and managers responsible for strategic orientation of enterprises.
The first question in the survey was: Does your company have defined one of these strategies? It was closed question with options for answer: complex logistics strategy; partial logistics strategies (purchasing, distribution, warehousing...); none of these options; other. Approximately 23% of the companies surveyed have a complex logistics strategy, approximately 15% have developed a complex logistics strategy and some of the partial strategy: purchasing, distribution, warehousing, production logistics, and up to 46% have only partial logistics strategy (purchasing, distribution, warehousing, production logistics). In

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companies the formation of partial strategies prevails, but logistics has an integrative function in the company and therefore the individual strategies should be matched in one common logistic strategy.

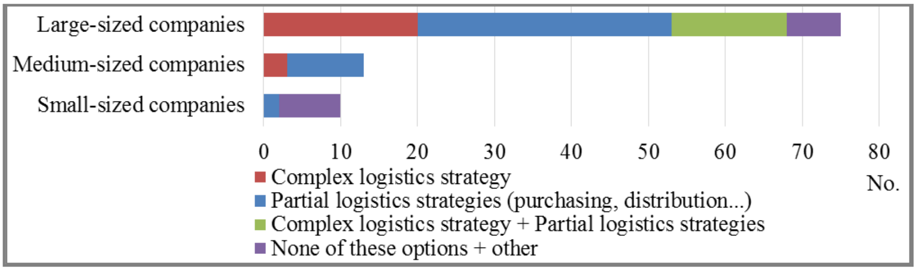

Fig. 1. Creation of logistics strategy by companies divided into groups according to size

Fig. 1. shows the breakdown of respondents by size and their responses to the development of logistics strategies. For medium-sized companies, the distribution of the complex logistics strategy and partial logistics strategies is 20% to 80%. A much larger part has only partial logistics strategies. Here is the space for creating a methodology for development a complex logistics strategy for medium-sized companies.

2. MODEL OF LOGISTICS STRATEGY DEVELOPMENT

The term logistics has a commonly used definition: management of the flow of product from source to point of use. But the concept of a logistics strategy and how it relates to all components of logistics is often confusing for practitioners. If you ask ten managers what are the key issues which should be involved in logistics strategy you would get ten different answers.

Making quick, informed decisions can save a company up to 40% on logistics costs, so one of the best practices in logistics management is to implement a fine-tuned logistics strategy. Developing and implementing a formal logistics strategy will add flexibility to the decision-making process and increase error-response time.

The development of the logistics strategy was based on the model of the strategic management process by Wheelen - Hunger. The four basic phases of the development and implementation of the new strategy have been used, but they have been modified, adapted to the logistics environment and complemented by the preparatory phase. The logistics strategy model is divided into five phases:

- preparatory phase,
- analytical phase,
- formulation of variants of the logistics strategy,
- implementation of the logistics strategy,
- evaluation and control of the logistics strategy.

At the outset, it should be noted that there are slight differences in whether we are creating a logistics strategy for a greenfield or brownfield.

In Fig. 2. is depicted logistics strategy development model, which consists of five main phases. In each phase are described partial steps, which should be performed.

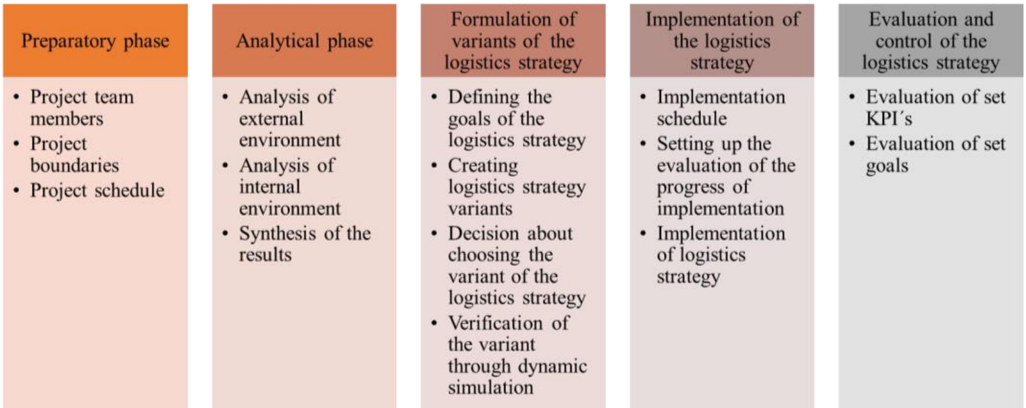

Fig. 2. Logistics strategy development model

2.1. Preparatory phase

The preparatory phase of the logistics strategy is designed to verify the topicality of the logistics strategy if it already exists; find options for partial corrective actions to update the strategy; build a project team which will participate in the creation of a logistics strategy; define the boundaries of the logistics strategy development project and build a schedule for creating a logistics strategy.

2.2. Analytical phase

Before an organization can begin strategy formulation, it must scan the external environment to identify possible opportunities and threats and its internal environment for strengths and weaknesses. When we speak about logistics strategy, we must consider factors which influence logistics processes. Internal scanning can be performed by logistics audit. There are mainly technological and ecological factors in external environment which have a significant impact on logistics. Synthesis of results from analyses can be performed by SWOT analysis.

2.3. Formulation of variants of the logistics strategy

Once environmental scanning is completed, situational analysis calls for the integration of this information. Now the company knows which are its strengths and weaknesses and which opportunities and threats have an influence on logistics processes.

Logistics strategy formulation is about definition of objectives and policies. Objectives are the end results of planned activity. They should be stated as action verbs and tell what is to be accomplished by when and quantified if possible. Objectives should be SMART: Specific, Measurable, Achievable, Realistic and Time-bound. For example: „to decrease the logistics costs in 2010 by 10% over 2009“.

Subsequently, the project team may develop logistics strategy variants following the results of analyzes that are not currently being undertaken without the implementation of latest information and communication technologies. To speed up decision-making and verifying partial solutions, it is appropriate to use the elements of the digital factory. If the variants do not meet the set goals, they need to be modified. When choosing a variant, the suggested indicators are considered. The chosen strategy option is appropriate to verify using dynamic simulation.

2.4. Implementation of the logistics strategy

After choosing an appropriate strategy option, the project team has to create an implementation schedule that, like the schedule of the entire strategy, includes project activities, activity continuity, duration of activities and time milestones, critical path, assigned human resources and costs.

2.5. Evaluation and control of the logistics strategy

The fact if the implemented strategy is effective should be controlled through measurements of the logistics processes performance. Key Performance Indicator (KPI) is a performance measure, a yardstick for tracking progress and a tool to achieve a goal. At this stage, it is necessary to follow the established indicators and to take corrective action when the deviation is detected according to predetermined rules.

3. CONCLUSION

From the perspective of a successful and competitive company it is a necessity to deal with the creation of logistics strategy of the company. Logistics is the area where it is still an enormous potential for cost reduction, it is only necessary to invest in the right technologies that will deliver the desired results in the long term to a particular company. Measure the results of the logistics business is possible using a variety of performance indicators. Here, too, it is essential to choose only some of them having explanatory power to enterprise.
The proposed model of development a logistics strategy provides medium-sized companies with guidance how to develop a logistics strategy with regard to using progressive tools and new trends in information and communication technologies.

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